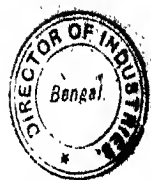


THE
VOLATILE OILS



THE VOLATILE OILS

BY

E. GILDEMEISTER AND FR. HOFFMANN.

SECOND EDITION

BY

E. GILDEMEISTER.

Written under the auspices of the firm of
SCHIMMEL & CO., MILTITZ NEAR LEIPZIG.

Authorized translation by
EDWARD KREMERS
MADISON, WIS.

FIRST VOLUME.

WITH TWO MAPS AND NUMEROUS ILLUSTRATIONS.



LONGMANS, GREEN, AND CO., 39, PATERNOSTER ROW, LONDON,
BOMBAY, AND CALCUTTA.

1913.

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PREFACE TO THE SECOND EDITION.

Eleven years have passed since the publication of the first edition. During this period enormous progress has been made, scientifically as well as practically, in the realm of the volatile oils. Numerous investigations have increased and broadened our knowledge of the volatile oils. The composition of a considerable number of volatile oils, heretofore unknown, has been revealed. New chemical compounds, the presence of which in volatile oils had, previously, not been established, have been found therein. The industry has not hesitated to utilize the results of these investigations. It has applied them to the methods of testing volatile oils and has improved these methods. The distillation of new volatile oils has greatly added to their number. All of these causes, as well as the circumstance that the first edition has been exhausted since several years, have induced me to begin work on a second edition.

Inasmuch as the material had grown too voluminous to be included within one volume, the book now appears in two volumes.

The first volume, now completed, contains the historical part, including the history of the several oils. This part had been written for the first edition by the late Dr. Friedrich Hoffmann. It remains almost unchanged and has received only occasional supplements. In addition, the first volume also contains the description of the principal constituents of the volatile oils, as well as the methods of testing them.

A new chapter has been added on the "Production of flower perfumes by extraction, *enfleurage* and maceration". During the past decade these methods have acquired considerable importance, more particularly in Southern France. The chapter devoted to the "Theoretical basis for obtaining volatile oils by

steam distillation" has been omitted. Being of the greatest industrial importance, it was carefully revised and amplified by Dr. C. v. Rechenberg, and, inasmuch as other matters, not pertaining directly to volatile oils, had to be included in the treatise, it became so bulky as to necessitate a separate volume. This has already made its appearance under the title: "Theorie der Gewinnung und Trennung der ätherischen Öle durch Destillation (Grundzüge der allgemeinen Destillationslehre)."

For their co-operation in the chapter: "The principal constituents of the volatile oils," which includes the principal artificial perfumes, I am indebted to Dr. O. Wiegand, Dr. A. Reclaire, Dr. H. Köhler, and Dr. W. Müller. The chapter on "The examination of volatile oils" was revised by Dr. O. Wiegand. All of these gentlemen, as well as Dr. F. Rochussen, have assisted in reading proof.

The tables contained in the first edition have been expanded and a new one has been added. Using 1.5 g. of oil and a half normal potassium hydroxide solution, this table enables the analyst to read off directly the ester value, also the percentage of ester and alcohol, without any computation. A second copy of these tables has been added to the book in such a manner that they can be used separately in the laboratory.

In the second volume, which is to appear later, the individual volatile oils are to be dealt with.

MILTITZ near Leipzig, July 1910.

E. GILDEMEISTER.

PREFACE.

It is only within the last few decades that the former empiric manufacture of volatile oils has been placed on a scientific basis, which has enabled it to develop into an independent branch of chemical industry. During the period of transition in which this branch still finds itself, those factories which have done pioneer work, both scientifically and technically, as well as those which use the oils in various manufactures, are often compelled to suffer from the competition of inferior and adulterated products. As a matter of fact, the proper understanding of the estimation and appreciation of quality and purity of the much used volatile oils is not as common as is desirable for industry, commerce and the trades. The principal cause for this condition is the fact that the recent chemical investigations and their application to the arts have not yet been generally offered in suitable form.

The want of a work which from a modern standpoint treats in an exhaustive and critical manner the entire subject of volatile oils, has induced the firm of Schimmel & Co. of Leipzig to commission the authors with the preparation of a treatise that would meet the present demands. The successful completion of this task has been greatly facilitated by having placed at their disposal the observation records of many years of manufacturing on a large scale.

Special stress has been laid on the description of properties and on tried methods of testing the commercially more important oils. Thus the consumer is placed in a position to distinguish pure from adulterated oils, good oils from those of inferior quality. Inasmuch as rational methods of examination are dependent on a knowledge of the physical properties and chemical composition of the oils, it became necessary to discuss thoroughly the results

of the scientific investigations of the subject. Those investigations, however, that cannot claim permanent value, as well as antiquated methods, such as color reactions, etc., have not been included.

Fully realizing the importance of a historical basis for such a work, this has received special attention. Detailed references to the original sources enable the reader to make further investigations in this direction.

Although the aim and object of this book is primarily of a practical nature, the authors venture to hope that it also offers to the scientific investigator a complete summary, with numerous references to original literature, of everything that has been accomplished in this line.

The authors acknowledge with thanks the co-operation of Dr. C. von Reichenberg who wrote the chapter "Theoretical foundation for the preparation of volatile oils by steam distillation;" also of Dr. J. Helle who contributed "The more common constituents of volatile oils;" finally that of Dr. J. Bertram who kindly assisted in reading proof and who repeatedly made valuable suggestions.

With regard to the share in the work by the two authors whose names appear on the title page: the "Historical introduction," also everything that pertains to the history of the volatile oils and the raw materials, as well as the description of the methods of production of the American products, and in part the statements regarding origin and production of the drugs, are from the pen of Dr. Friedrich Hoffmann; the entire chemical text and those parts not specially enumerated have been written by Dr. Eduard Gildemeister.

LEIPZIG and BERLIN, June 1899.

PREFACE TO THE AMERICAN EDITION.

In the work of Doctors Gildemeister and Hoffmann we find a happy blending of history with chemical science and technology that is quite unique in modern chemical literature. Moreover it covers a chapter of organic chemistry of which Professor Emil Fischer of Berlin recently remarked that it had undergone more rapid development within the past fifteen years than any other.

The translation of such a work should indeed prove of value. To make such a translation and to take cognizance of the numerous contributions on volatile oils and related subjects that have appeared since the original German edition was issued a year ago, has proved a severe task for one whose time was already divided between instructional duties and editorial labors. In judging the English edition, it is hoped that the limitations as to time and the difficulties encountered will be taken into consideration.

Owing to the impossibility of satisfactorily translating many of the numerous quotations in the historical introduction, chapters two and three have been condensed. Inasmuch as but very few if any readers are in a position to consult the numerous historical works quoted by Dr. Hoffmann, all bibliographic information has been placed in an appendix.

To the special part a few oils were added, and changes rendered necessary by recent investigations were made as far as time permitted.

The writer desires to acknowledge with thanks his indebtedness to Mr. Carl Fritzsche and to Dr. Hoffmann for suggestions, as to the scope of the translation and as to minor details. Mr. O. Schreiner has assisted in the translation and proof reading and Dr. C. Kleber of Garfield, N. J., has kindly read one proof. His long experience as chemical expert on the subject of volatile oils rendered his co-operation especially valuable.

MADISON, WIS., July 1900.

EDWARD KRÉMERS.

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ERRATA.

- p. 25, line 1. Read Attafir for Attafin.
- p. 76, line 13. Insert between "discovery" and "of" the following words:
of the elementary composition of water by Cavendish about 1766 and
- p. 111, line 13. Hyphenate the word Card-ammomum.
- p. 115, after last line insert: Rheede also described pepper oil in 1688).
- p. 116, second last line, Read Masudi for Madusi.
- p. 121, line 19. Read Redi for Redis.
- p. 130, line 11. Read *medico-physica* for *medico-chymica*.
- p. 134, line 7. Read Guibourt for Guibort.
- p. 140, line 3. Read VII. for III.
- p. 144, line 8. Read Charlard for Charland.
- p. 146, line 15. Read Gerhardt for Gerhard.
- p. 148, 3rd line from below. Read Edrisi for Idrisi.
- p. 170, lines 4, 5 and 12. Read parsley for celery.
- p. 171, line 1. Read parsley for celery.
- p. 177, line 8. Read Engelbert for Adalbert.
- p. 179, line 15. Read Uschak for Uschaq.
- p. 188, line 7. Read Begninus for Begnini.
- p. 249, line 26. Read lighter for ligther.
- p. 474, The account under dihydrocuminic alcohol should be supplemented
by the following statement: Its naphthyl urethane is a solid com-
pound that melts between 140 and 174°. (Report of Schimmel & Co.,
Oct. 1906, 40.)
- p. 412, line 15. Read pyroracemic acid for pyruvic acid.
- p. 443, line 7. Read Beyer for Baeyer.
- p. 457, 7th line from below. Read benzoate for succinate.
- p. 521, line 17. For *imperialis* read *imperiale*.



HISTORICAL INTRODUCTION





I. THE SPICE-TRADE IN ANTIQUITY AND DURING THE MIDDLE AGES.

(With two maps.)

Parts of plants as well as natural plant products which have been used since antiquity on account of their agreeable odor, their pleasant taste, or their medicinal virtue, enter the world's commerce up to the present time in their original form, being either previously dried, or prepared in some other expedient manner. The essential constituents of these crude materials (drugs), the aromatic volatile oils, the resins, gum resins, bitter principles, alkaloids, and glucosides, have been recognized in the course of the development of the natural sciences. With the improvements in technology they have gradually been prepared in a purer and better condition.

Of these various products of the plant world, the spices and aromatics have from the very beginning ministered to the needs and welfare of man, and have, therefore, been appreciated by him in a special degree. As a result, they have always been a prominent and influential factor in the intercourse of nations as well as in the world's commerce. After several thousand years of knowledge and actual use of the spices in their original form, their essential constituents, the volatile oils, have since the middle ages and more particularly in modern times been successfully isolated and utilized.

In a treatise on volatile oils, a brief historical retrospect of the origin of and commerce in the bearers of these products, viz. the spices and aromatics, may be regarded as eminently proper. This all the more, since in this branch of knowledge as well as in others the historical element constitutes a valuable basis for a proper understanding and investigation.

All investigation in the realm of the history of civilization, that considers not merely a single people but mankind in general, and that goes back to the earliest historic documents, invariably leads to the wonderful orient so rich in legends—to central Asia, the traditional cradle of mankind. This is also true of the history of the trade of the oldest peoples, and especially of the source and distribution of the useful spices and aromatics.

Its geographical position and topographical configuration make Asia a very highly favored continent. Broad as it is, it extends from pole to equator. Favored by mighty mountain chains and rivers, its most beautiful and richest countries lie in latitudes where soil and climate afford all conditions favourable to luxuriant subtropical vegetation. The eastern and southern coastlands are cleft by large bays which penetrate far inland. Many navigable rivers which flow into these bays have their origin in distant highlands. The mainland is bordered by a wreath of islands extending from the Japanese island realm through the Malay archipelago to Ceylon. These islands abound in tropical vegetation. The entire continent, therefore, reveals a diversity and richness of plant life such as no other possesses.

These advantages have made southern Asia and the islands bordering on its coast the oldest and principal scene of international traffic and commerce, spices and aromatics constituting the main articles of exchange. They not only found general use on account of their agreeable odor and aromatic taste, but were employed by most peoples in religious rites and sacrificial customs, and thus acquired symbolic meaning. With the increase of prosperity and luxury, also with the development of the sense of cleanliness and of physical wellbeing, spices and aromatics not only became more valuable, but their consumption increased.

According to documents discovered in recent years, the territory between the Indus and the Oxus was the starting point of the early commerce between the oldest peoples of central and southern Asia. Attock, Cabura, Bactra, and Maracanda seem to have been the first larger centres for storage and exchange of oriental products. These consisted of spices and aromatics, the noble metals, silk, and jewelry. To Attock were brought the products of the eastern Chinese empire, which, at an early date, closed its markets to the rest of the world.

From Attock, at the junction of the Kabul river with the Indus, the caravan road led via Cabura (the present capital Kabul of Afghanistan) to the north via Bactra, Bochara, and Maracanda (Samarkand) to the countries of the Oxus and to the Scythian tribes. Also from Cabura southward to Kandahar, thence in a western direction through the realm of the Parthians to the *Pylæ Caspiæ* (Caspian gate), and to Ecbatana in Media. Thence the land route crossed the Tigris to Babylon on the Euphrates. In a later period, after the traffic along the water routes had developed, a round-about way via Susa to the mouth of the Tigris was taken and the caravan freight shipped up the Euphrates to Babylon. Between Attock and the ports on the Black and Mediterranean seas, Babylon—existing 3000 years B. C. — was in early antiquity the most important place of traffic and commerce for westward bound Chinese and Indian merchandise. To the northward the caravan roads led out of Babylon through Assyria and Armenia to the Black sea (*Pontus Euxinus*) and westward through Syria to the Mediterranean sea (*Mare Internum*), thence through Palestine to Egypt. In spite of their highly developed industry the Egyptians, as is well known, closed their doors to foreign peoples as did the Chinese. As a result commercial centres were wanting in Egypt that were open to foreign merchants and to transitory commerce.

During the prime of the Babylonian empire, about 2000 to 1000 B. C., a lively caravan trade was developed which extended from China, India and Arabia to Egypt, Palestine, Syria, and the Black sea.

During this period, Arabia acquired special importance by means of the sea traffic of her southern coast, which was favored by the Persian gulf and the Red sea. At an early date, the Arabian population conducted a lively intermediate trade with Indian and Egyptian goods which were brought to the Arabian ports. By means of caravans these were carried northward to Babylonia, Syria, and other countries. The principal route from southwestern Arabia to Babylon, Damascus and Egypt led from Cane on the Arabian gulf (Erythraean sea) via Saba, Macoraba, Hippos, and Onne to Elath (the present Akabah) at the north-eastern end of the Red sea. From this point the eastern route crossed the Jordan via Petra, Kir Moab, Ammonitis and Dan to

Damascus; the western route to Egypt via Azab, Axomis, and Meroë.

About 15 centuries before the Christian era, the world's commerce was gradually and, in the course of time, very greatly expanded by the Phœnicians, who lived on the narrow Syrian coast district. In the industrial and commercial field they acquired a prominent position; as mariners, however, a dominating position among the nations of their time. Besides having practical control of sea navigation, the Phœnicians were the first extensive and successful colonizing nation of antiquity. They established or extended commerce with the peoples living along the coast of the Mediterranean, they ventured through the "Pillars of Hercules" (Gibraltar) into the ocean and made accessible the products of the Madeira and Canary islands, the western coasts of Spain and France, the British islands, and the northland as far as the amber coasts of the Baltic sea.

For almost a thousand years, during which time they held their prominent position in marine traffic, the Phœnicians were the principal commercial agents between the nations of the orient and the occident. Sidon and, since the ninth century B. C., Tyre became prominent centres of the world's commerce of that time.¹⁾

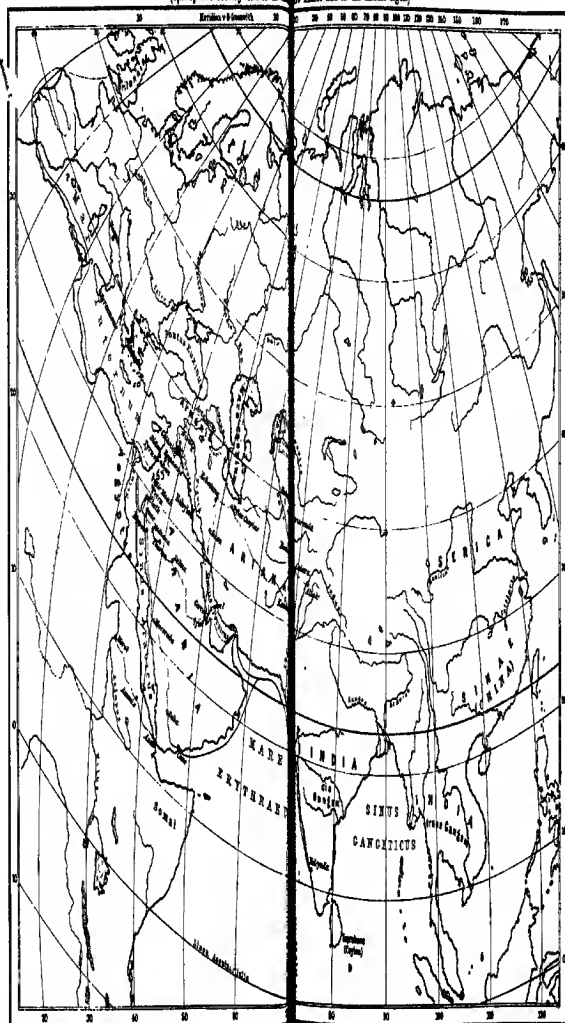
The Phœnicians also extended their navigation to the Red sea and the Arabian gulf and from these to the Persian gulf. In the latter they established the colonies on Arados and Tylos, islands belonging to the present Bahrein group. From the twelfth century up to their decline in the fifth century B. C., these cities carried on a large transit-trade with goods from India and Ceylon to Babylon, Damascus, Tyre and Sidon, and to Egypt. A caravan route led from Gerra via Salma, Thæma and Madiana to Elath. From Elath the older routes to the north, to Damascus, Tyre and Sidon were followed, also westward to Egypt. To Babylon, on the other hand, the water route up the Euphrates or Tigris was taken from Arados and Tylos.

Carthage, a Phœnician colony established in 846 B. C., soon flourished and developed such power that it became the greatest rival of the mother country in the following century.

¹⁾ As is well known, the Phœnicians supplied King Solomon with the material for the building of the temple at Jerusalem about 1000 B. C. (1. Kings, 5, 9 and 10; also 2. Chron., 2 and 9).

THE HIGHWAYS OF COMMERCE IN ANCIENT TIMES.

(Spice and Grocery Trades in Ancient Times and in the Middle Ages.)



London: J. W. & J. R. Ballantyne.

Printed by J. W. & J. R. Ballantyne.

Owing to the rise of the Persian empire, the inland commerce of western Asia was somewhat shifted during the period from the sixth to the fourth century B. C. The old routes of traffic passing through countries controlled by the Persians were not only kept in good condition but extensions were also made. These old highways of transcontinental commerce underwent further changes at the time of the Greek conquests under Alexander the Great at the close of the fourth century B. C. Still greater, however, were the changes brought about by the migration of nations during the fourth and fifth centuries of the Christian era. Wars and other disturbances of the commercial intercourse along the old caravan routes frequently restricted traffic to the rivers and seas. Upon the re-establishment of peace, however, commerce always seems to have found its way back to the traditional caravan routes.

In the course of time, however, and especially during the sixth and seventh centuries still other changes took place. Thus, e. g. the products of the Chinese and Indian coast districts and of the Indian islands were brought in part by ship over the Bay of Bengal and by way of Ceylon to the commercial centres of the Persian gulf and the Red sea. From these they were distributed by coast-wise trade, by river navigation up the Tigris and Euphrates, or by caravans to the north and west. From the more northern Chinese and Indian districts the caravans passed through the present East-Turkestan following the older routes mentioned on p. 8 and 9 through the countries of the Oxus to the Araxes. The goods, instead of being carried by river to Phasis and the Black sea, were taken as far as Artaxata and then by caravan through Persia to the ports of Asia Minor. The old route from Kandahar along the northern border of the Iranian plateau, which likewise led through Persian territory, was also followed by caravans.

During the reign of the East Roman emperor Justinian, in the sixth century, when the world empire of the Romans was broken up by the migration of nations, Persia experienced a new rise to power under the Sassanidæ. The Persians ruled the entire territory from the Caspian to the Arabian seas and from Afghanistan of to-day to Syria and Armenia. They improved the old high-ways and caravansaries, kept them in repair and

promoted commerce and traffic, directing both over routes leading through their own territory. Owing to the wealth and luxury of the Roman empire, the commerce in oriental spices had risen to an unusual height. The East Roman empire which at that time was the principal western state with its capital at Constantinople, was forced by the Persians to procure such oriental goods as were not shipped by water, from and through Persia and to pay a heavy duty on them. The principal places of storage and for the collection of revenue at that time were Artaxata on the Araxes, Nisibis, south of the Tigris, and Callinicum (Rakka) on the Euphrates. To Artaxata were brought the goods from the countries of the Oxus over the Caspian sea. Those that were conveyed along the caravan routes south of the Caspian sea, and those that came from the coastlands of the Persian bay up the Tigris or Euphrates centered at Nisibis. For nearly five centuries, the aromatics of China and India, of the Malayan archipelago which came via Ceylon, and in part those of Arabia were transported over the two last-mentioned routes to the western countries. About this time also, the Levant commerce, which became so important in a future period, had its beginning.

During the life of the Persian empire (up to the middle of the seventh century A. D.) all attempts, made by Justinian and his successors, to divert the commerce from its course through Persian territory by means of marine transportation remained unsuccessful. They did not even succeed in opening up marine traffic between India and Ethiopia, because Persian merchants visited the Indian markets and persuaded the Indians and Chinese not to sell their goods to new customers. In the course of time, however, the Greeks succeeded in obtaining larger consignments by water from the ports of India and Ceylon and more particularly from the coastlands of the Arabian sea, which were rich in spices. These were delivered directly to their own ports, Kolsum, and Akabah and Berenice near the entrance to the Red sea.

About this time there existed three great caravan routes from China westward. They began in the territory of the Hoang Ho and the Yangtsekiang and passed through the Gobi desert. The northern route took its course through the oasis of Chami,

then northward along the Thian-Shan mountains through the present Dsungarai, past the Balkash sea, and via Talas. It then followed the Syr-Darya river to the Aral sea and the Caspian sea.

The middle route passed to the south of the Thian-Shan mountains through the northern part of East Turkestan via Chami, Turfan, Karashar, Kutsha, and Aksu to Kashgar; thence over the Terck pass to Ferghana via Samarkand, Buchara and Merv to Persia.

From the Gobi desert, the southern route passed through the southern part of East Turkestan via Chotan and Yarkand, then over the Pamir plateau and through Afghanistan to the Punjab (India) crossing the Bamian and Gazna passes to Multan. Goods intended for the west, coming via this route, were taken down the Indus river to Daybal. From this port they were shipped by sea with other goods from India and Ceylon.

During the seventh and eighth centuries A. D. the Arabs carried on an extensive marine commerce with India and China, especially in spices and aromatics. These were supplied in large quantities to the luxurious courts of the caliphs and the Byzantine emperors. The principal centres between China and Arabia were at that time on the Malay peninsula, to which were also brought the products of Java and other Sunda islands. Later on commerce concentrated itself in Kalah, a city on the east shore of the Malay peninsula. In the tenth century there existed between Kalah and Siraf, a city on the east coast of the Persian gulf, regular commercial intercourse between the Arabians and Chinese. From the northern point of Sumatra the Chinese crossed the bay of Bengal to Ceylon.

Arabian merchants also settled along the Malabar coast, in Ceylon and in the Indian sea ports. From the eighth to the tenth century, Daybal at the mouth of the Indus was the important commercial centre and seaport of India. It was the principal emporium for the products of the Indus valley and the Punjab on the one side and of Mesopotamia, Persia and Arabia on the other. For the products of northern India, Multan on the Djelam river in the Punjab, was the first larger rallying point. It was also a place of pilgrimage that was much revered and visited by the Hindoos.

From the eighth century on, Suhar and Muscat, near the entrance of the Persian bay, developed as rival ports for Indian and Chinese commerce with occidental countries. At the same time Aden, at the entrance to the Red sea, became the principal port and commercial centre for the products from Yemen, Hedsjaz, Ethiopia and Egypt.

In addition there were caravan routes: one from India to Persia through Seistan; the other via Gazna and Kabul to Afghanistan.

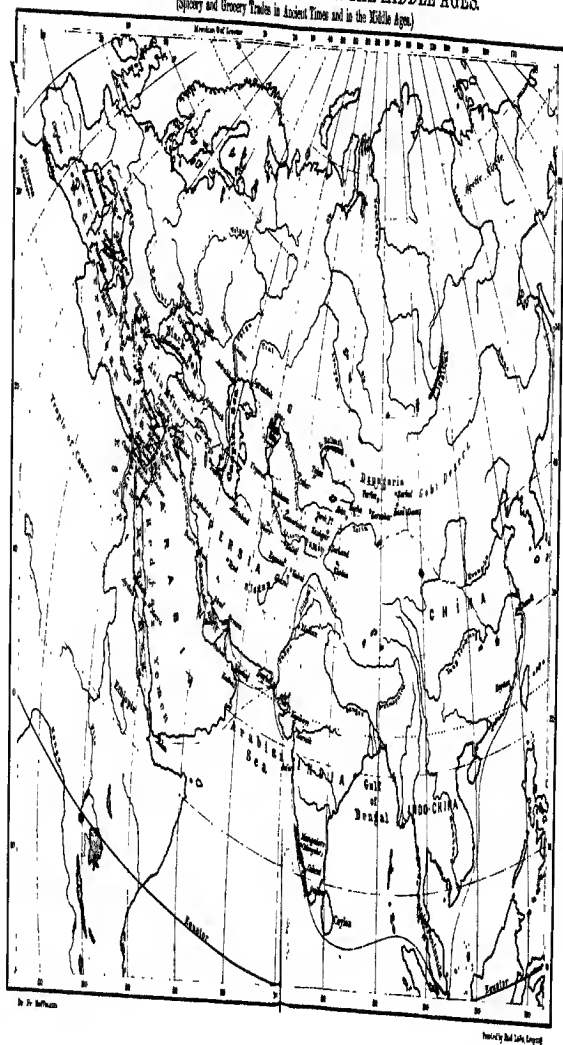
Seti I. and Rameses II., Egyptian pharaohs, had during the first quarter of the fourteenth century B. C. connected the Red sea with the Mediterranean sea. In order to re-establish this sea-route, Pharaoh Necho toward the end of the seventh century B. C. tried to have a new canal constructed from Bubastis on the Nile to Patumos on the Red sea. This was not completed, however, until 500 B. C. by Darius Hystaspes and was widened and improved by the Ptolemies. Before the beginning of the Christian era it was again choked up with sand. Under the caliph Omar in the seventh century A. D. the canal from Cairo to the Red sea was again restored, but did not exist longer than a century.

From the seventh to the twelfth century there also existed several land routes across the Suez isthmus. One of these followed the course of the old canal (choked up with sand) from the Red sea to Cairo, whence the goods were shipped down the Nile and then by sea. If the passage of the goods through Alexandria was not necessary, the shorter route over the isthmus from Kolsum to Pelusium (Faramiah), was preferred. At this time Damascus and Jerusalem were also important commercial centres. Here also oriental goods were exchanged by the merchants of Mecca on the one hand and those of Tripoli, Beirut, Tyre and Acre on the other.

From the seventh to the twelfth century there existed an active coastwise trade along the north African coast, having its centres in Syria and Egypt and extending as far as Morocco and Spain. This commerce acquired a special importance for spices and aromatics although for a time it was limited by Mohammedan laws against intercourse with Christians. Commerce also soon flourished among the Greeks, who obtained spices and aromatics, possibly also rose water and aromatized fatty



(Spicery and Grocery Trades in Ancient Times and in the Middle Ages)



oils from Antioch, Alexandria and Trapezunt and brought them to Constantinople, Thessalonica and Cherson. Already in the tenth century Trapezunt was an important emporium for the drugs of India and Arabia and for Persian perfumes. The Greeks, however, purchased these luxuries only for home consumption, which was large, without distributing them farther to other nations.

From the tenth to the fifteenth centuries, the commerce of the Mediterranean was conducted principally by Italian cities. In the tenth and eleventh centuries Bari, Salerno, Naples, Gaëta, and above all Amalfi, Pisa and Venice were the principal commercial centres. The Levant commerce, which was in its prime from the twelfth to the fifteenth century centered in Venice and Genoa. In the Levant itself, at the time of the crusades during the twelfth and thirteenth centuries, Acre on the Palestine coast was the most important commercial port. When this city, the last one held by the Christians, likewise fell into the hands of the Mohammedans in 1291, Famagusta on Cyprus, and, for a longer period, Lajazza on the bay of Alexandretta, became the commercial centres of the Levant up to the fifteenth century. The latter port was the junction for the western merchants with those coming from Asia.

Toward the end of the thirteenth century, the cities of Bagdad and Basra on the Euphrates, lost their commercial supremacy which they held for several centuries to Tebriz, the new rising capital of Persia near the Caspian sea. When Egypt in the thirteenth and fourteenth centuries began to levy a high toll on the finer Indian spices and aromatics, the land transportation was deviated more and more through Persia via Bagdad and Tebriz to Lajazzo and Trapezunt.

During the fourteenth century, the island port Ormuz in the Persian gulf became an emporium for the westward-bound goods from India and Ceylon. It maintained this position until its capture by the Portuguese at the beginning of the sixteenth century. The more important ports along the western coast of India at that time were Mangalore, Calicut and Quilon. Ginger, cinnamon, cardamoms, pepper, cloves, nutmegs, sandalwood, lignaloës, indigo, etc., were brought to these ports from the interior. From the Chinese ports and the East Indian islands large importations of these and similar drugs were received.

Toward the close of the thirteenth and at the beginning of the fourteenth century the direct traffic between Europe and China became very active, more particularly over the land route. Under the protection of the Mongols the caravan routes through central Asia were generally safe. The greater part of the Chinese empire was also accessible to Europeans. About this time also Marco Polo, the first European world-traveler, visited China, India and the islands of the Indian ocean.

Owing to disturbances and invasions of central Asia, the overland traffic diminished after the middle of the fourteenth century. Up to the discovery of the sea route around Africa at the close of the fifteenth century, Tebriz, however, remained an important centre for transitory trade. The capture of Constantinople by the Turks in 1453 enabled them to interrupt the trade of the Italians via Trapezunt and the Crimea and soon to cut it off altogether. About this time Cyprus also lost its former importance for the Levant trade.

Egyptian commerce, however, once more increased considerably toward the close of the fourteenth and in the course of the fifteenth century. In place of Aden, Djidda, the sea-port of Mecca, became the principal junction of commerce between the Indian seas and the occident. The heavier goods were transported by water, the lighter by pilgrim caravans to Tor on the Sinai peninsula. The high toll levied by the Egyptians caused some of this trade to be deviated for the time being to Syria. Owing to the occupation of Lajazzo by the Turks in 1347, and the conquest of the Crimea in the fifteenth century, this traffic continued to develop for a short time.

Thus in the course of several thousand years, the commercial intercourse between the nations of Asia, later also those of Africa and of Europe underwent a variety of changes as did also the various routes of traffic. The circumnavigation of Africa by the Portuguese in 1498, their conquest of Ormuz, the key to the Persian gulf, and their extended marine traffic brought about important changes in the traditional channels of traffic. The transport by means of caravans was gradually diminished; the highways, formerly well kept, got out of repair, the ocean ship displaced the "ship of the desert", the camel of the caravans.

From the sixteenth century on, the ocean became the preferred highway of international commerce. Hence the Levant commerce, which had flourished for several centuries and had enriched the commercial centres of Italy and of other Mediterranean countries, lost its importance.

Numerous ruins of magnificent buildings in cities and markets, well built high-ways covered with the sand of centuries, also caravansaries on the plateau and desert lands of western Asia and the Arabian peninsula reveal to these after-days the former greatness and the commercial prosperity of peoples who still live in history but principally in name only.

The spices and aromatics of southern Asia and the Asiatic islands, which constituted the first foundation of international commerce have retained their original value in spite of all changes in the world's history. The same spicy cinnamon, cloves, nutmegs and cardamoms, pepper and ginger and other spices used and highly appreciated since antiquity; frankincense and myrrh, benzoin and other incenses, camphor, sandalwood and lignaloes and other plant products acquiring use in ever increasing numbers thrive after thousands of years in the sunny countries and islands of the orient in primeval profusion.

However, they are no longer brought to the occident on the backs of camels over the plateaus and deserts of Asia, but in trim sailing vessels and speedy steamships crossing the ocean; or they are transported in freight cars that hasten over steel tracks encircling the continents. They are used up to this day, in the humble hut as well as in the palace of the rich, either in their original state, or in a concentrated form, purified by the giant stills of modern chemical industry.

II. GENERAL HISTORY OF THE VOLATILE OILS.

In the course of centuries various more or less independent branches have separated from the common trunk of natural science and have made a history of their own. This is true of the subject presented in this treatise. To be sure a fairly exact knowledge of those plant products, which are termed volatile oils, has been gained only in recent periods. Nevertheless the nature and value of these substances does not appear to have escaped the observation of the oldest peoples. It seems almost certain that not only the grace and vivid coloring of the flowers but also the fragrance of the vegetation in southern Asia must have aroused the curiosity of man, fully as much as did the utilization of the plants for the purpose of food and clothing. Indeed, those plants and plant products that were conspicuous on account of their aromatic odor and taste, seem to have attracted the attention of man in a special degree. These very properties seem to have induced him to use them and to seek proper methods for their cultivation and preservation.

It is true that the oldest documents pertaining to the history of the beginning of human industry have recorded only the most primitive methods for the preparation of implements that were used in the chase, the cultivation of the soil, and for the collection and preparation of foodstuffs and other useful products. Nevertheless it may not be amiss to suppose that the exigencies of self-preservation and of wellbeing at an early period caused man to utilize fire not only for the preparation of foodstuffs but for various other purposes. It may have required long periods of time before fire was used for the preservation of perishable foodstuffs, for the separation of pleasant substances from dis-

agreeable ones: so, e. g., the distillation of the "spirit of wine" from the wine itself; the separation of the "subtle principle", the aroma, from spices which were among the earliest articles of barter and commerce during antiquity; and which as products of nature agreeable to the gods, were offered as sacrifices in religious ceremonies, and were also used in the embalming of the dead.

It is especially this use of spices and of aromatic plant products by the priests, those promoters and supporters of natural science during antiquity, that renders it probable that their knowledge was early applied to the production, and preparation of the spices which were used in the sacrifices and in embalming. Whether a beginning in the preparation of the aromatic principles of plants, our modern volatile oils, was made previous to early Hindoo and Egyptian civilization, does not become apparent from the oldest documents. Even the Bible, which gives so much information concerning the customs of the Jews, makes no other statements than those pertaining to the spices and aromatics used in various countries. The early preparation and utilization of the more common metals would indicate that furnaces and other apparatus for heating were used in a variety of ways. One may suppose, therefore, that they were gradually used in primitive attempts to separate the spirit from wine, from other fermented fruit juices and honey; also the aromatic principles from spices, balsams and oleoresins. These crude experiments may be considered as constituting the first stages in the art of distillation.

The Egyptians, owing to the continuity of their early and highly developed civilization and to the preservation of their monuments and literary productions, are generally considered as standing at the portals of history. With reference to time, however, the Chinese and Aryans are probably the oldest peoples. These races, with whom civilization seems to have had its beginning, lived in central and southern Asia, a mountainous district favored with a mild climate and a luxuriant vegetation rich in useful and spicy products. Our knowledge of the peoples who first occupied this wide territory is but legendary. Concerning their industrial and technical accomplishments but little definite information has come down to us. These Chinese and

Indians may have developed considerable dexterity in industrial pursuits and may even have accomplished much in the scientific realm. Their attitude of exclusiveness, however, toward the outside world and their secrecy have prevented them from exerting a lasting influence on other nations. The oldest documents that throw light on their early scientific accomplishments are the *Ayur-Veda* (Book of the Science of Life) by Charaka and Susruta.¹⁾ As is the case with so many writings of early antiquity, nothing definite is known with regard to the age of these documents. It is possible that they are traditions reduced to writing at a rather late time.²⁾ From this work it becomes apparent that the Indians were acquainted with primitive apparatus for distillation, with fermentation and the products obtained by distillation. Of "distilled oils", those of rose, schœnus (andropogon), and calamus are mentioned.³⁾ Whether these oils are "distilled" in the modern sense of this term can not be ascertained.

From documents of the old Persians it would seem that they also were acquainted with the process of distillation and hence with distilling apparatus.⁴⁾

With regard to the Egyptians, however, whose history goes back as far as 4000 B. C., we have definite information concerning the early development of industry, art, and science. Their commerce, which extended as far as India, Babylonia,

¹⁾ Susruta's *Ayur-vedas, id est medicinæ systema a venerabili D'hauvantare demonstratum a Susruta discipulo compositum. Nunc primum ex Sanscrita in Latinum sermonem vertit, introductionem, annotationes et rerum indicem adiecit* Dr. Fr. Hessler, Erlangæ 1844.

The Susruta, or System of medicine, taught by Dhanvantari and composed by his disciple Susruta. Published by Sri Madhusudana-Gupta, Prof. of medicine at the Sanscrit College at Calcutta. Calcutta 1835. 2 Vol.

²⁾ Lassen, *Indische Altertumskunde*. 1. ed., vol. 2, 551.

J. F. Royle, *An essay on the antiquity of Hindoo medicine*. London 1837. Wallach and Heusinger, *Das Altertum der indischen Medizin*. Kassel 1839. p. 45.

Allan Webb, *The historical relations of ancient Hindoo with Greek medicine*. Calcutta 1850. p. 45.

Zeitschrift der Deutsch. Morgenländ. Gesellsch. 30 (1876), 617 and 31 (1877), 647.

³⁾ Susruta's *Ayur-vedas*. Editio Hessler. Erlangæ 1844. p. 111 and 130.

⁴⁾ Gebri *De alchemia libri tres*. Argentorati arte et impensa Io. Grieningeri anno 1529.

Chr. G. Schmieder, *Geschichte der Alchemie*. Halle 1832. p. 34.

Syria, Ethiopia and other countries, as well as their industry and art undoubtedly developed slowly before it reached that height which we now admire. Thus, they were acquainted with the preparation of the metals, with furnaces and distilling apparatus, with the distillation of wine, and of the oleoresin of cedar;¹⁾ with the preparation of soda, alum, vinegar,²⁾ soap, leather; also with the preparation and use of colors and the manufacture of glass. The Egyptians used cedar (turpentine) oil³⁾ and colophonium,⁴⁾ and probably knew how to isolate plant aromas as distilled oils.

The height which Egyptian civilization reached is revealed better by their architectural monuments, mummies found in the pyramids, and by the products of artistic workmanship, than by the few written documents that have come down to us. Likewise in the building of ships and in their commerce with neighboring countries the Egyptians accomplished much.

Like their writings, many of their arts and crafts were lost at least in part to the civilized nations succeeding them and had to be rediscovered. In judging the relationship between their scientific knowledge and their accomplishments in the arts and crafts, it should be remembered that the manufacture of metals, of glass, and even dyeing were based on a rather crude empiricism and seem to have been almost wholly independent of the theoretical consideration of the age. Thus, with but little scientific knowledge of permanent value, these most ancient peoples, the Hindoos, Egyptians, Assyrians, Babylonians and Phœnicians, like the Chinese, who stand at the dawn of civilization, have in the

¹⁾ Aetii medici græci *Ex veteribus medicinæ tetrabiblos*. Editio Aldina. Veneti 1547. fol. 10.

²⁾ Numbers, 6:3.

³⁾ Herodoti *Historiæ* II. 85.

Pedanii Dioscoridis Anazarbei *De materia medica libri quinque*. Editio Kühn-Sprengel. Lipsiæ 1829. Lib. 1, cap. 34, 39, 80, 95, 97.

Plinii Secundi *Naturalis historiæ libri 37*. Liber 15, cap. 6 and 7, and liber 16, cap. 22.

Scribonii Largi *Compositiones medicamentorum*. Editio Schneider. p. 323. Theophrasti Eresii *Opera, quæ supersunt omnia. Historia plantarum*. Editio Wimmer. Parisii 1866. Liber 9, cap. 3.

⁴⁾ Pedanii Dioscoridis Anazarbei *De materia medica libri quinque*. Editio Kühn-Sprengel. Lipsiæ 1829. Vol. 1, p. 660 and vol. 2, p. 639.

course of centuries of development accomplished much in a practical way. They, and among them the Egyptians more particularly, served as the teachers of the classical nations of Greece and Rome.

The scientific knowledge as well as the industrial and artistic accomplishments of the Hebrews and the Greeks, and indirectly also of the Romans, had their root in Egyptian civilization. However, the Greeks, like the Hebrews, tended toward the ideal rather than the practical in their conception of Nature. They did not experiment and were not bent on applying their scientific knowledge. The Greek philosophers and writers collected and systematized the information that had come down to them and thus aided in preserving it, without, however, putting it to practical use or adding anything new to it.

The Greeks, however, were well informed as to the Egyptian arts; they understood the preparation and working of the metals, the manufacture of glass, and other industrial arts. Their commerce, however, was mostly barter in natural products. The oriental spices were highly prized by them for incenses, cosmetic and sanitary purposes. Whether the primitive method of distillation practiced by the Egyptians and Persians was known to the Greeks does not appear from their literature. It is not improbable, however, for medicine and the use of cosmetics were hardly less thought of by the Greeks than by the Egyptians. Owing to the luxury of the later Greeks, perfumes and spices were extensively used. The much praised oriental perfumes, especially sandal wood (*Santalum indicum*) were considered a necessity at all festivities. Hence the Greeks procured the aromatics known to them as articles of barter. In later periods, however, the procuring of these products like the sea traffic generally was left to other peoples.

At the time when Greek culture spread westward and became the basis of Roman civilization, Greek views concerning nature and Greek knowledge of it were likewise transmitted. In their numerous conquests, the Romans increased their knowledge of oriental natural products. These were brought by the old caravan routes and then by sea to Rome. Among them were the finest spices for the kitchen, perfumes and ointments for the toilet, balsams and incenses. Whether only aromatized fats, or distilled

oils as well, were used cannot be ascertained definitely from Roman literature. That the Romans themselves were adept in the preparation of toilet articles seems highly probable. That the natural sciences, including the science of drugs, were well cultivated is shown by the writings of Dioscorides,¹⁾ Pliny²⁾ and Galen³⁾.

¹⁾ Pedanius Dioscorides was the first important writer on the history of drugs during the Christian era. Born in Anazarhus, in the southeastern part of Asia minor, during the first century, he traveled in the capacity of a physician with the Roman armies through several countries. The *Materia Medica*, written by him in the second half of the first century, was the most thorough work of its kind during antiquity, and was regarded as authority far into the middle ages. Thus it was used for purpose of comment as late as the time of Luther, as is evidenced by the lectures of Melanchthon at the University of Wittenberg and by the writings of Valerius Cordus in the middle of the sixteenth century.

The principal works written by Dioscorides in the second half of the first century are the five books, of his *De materia medica*, also his *Alexipharmaca et theriaca* (Remedies against plant and animal poisons) which were edited as books 6 and 7. These and other more apocryphal writings have been republished frequently and in many languages. Among the oldest editions are the Arabic manuscript in the library at Leyden, which possibly was written about the year 940; a very rare Greek edition printed *apud Aldum Manutium*, Veneti 1499; also a Latin edition by J. Altemannum de Medemblich, printed in Colle 1503. Of the better translations and commentaries the following may be mentioned:

Pedanii Dioscoridis Anazarbensis *De materia medica libri quinque*. Iano Coronario medico physico interprete. Basilae 1529.

Valerii Cordi Simesisii *Annotationes in Pedanii Dioscoridis Anazarbel De materia medica libros quinque, longe aliae quam antea sunt haec sunt emulgatae. Ipsidem historia stirpium libri quatuor, et de artificiosis extractionibus liber etc.* Translatio Ruellii. Francofurti ad Mennum 1549. Editio Gessnerii 1561.

Pedanii Dioscoridis Anazarbei *De medicinale materia medica libri sex*, Joanno Ruellio *Suessionensi interprete. Accesserunt priori editioni Valerii Cordi Simesisii Annotationes doctissimi in Dioscoridis de medica materia libros Euricii Cordi iudicium de herbis et simplicibus medicinis; ac eorum quae apud medicos controversantur explicatio.* Francofurti 1543.

Petri Andreae Matthioli *Opera quae extant omnia. Commentarii in sex libros Pedacei Dioscoridis de materia medica.* Veneti 1554.

Πιδανίου Διοσκορίδου Αναazarβίτου, περί τῆς ἐν τῇ φύσει φαρμάκων, ἢ: Pedacei Dioscoridis Anazarbei Opera quae extant omnia. Ex nova interpretatione. Iani-Antonii Saraceni, Lugduni Medici, Francofurti 1578 und 1598.

A Latin translation of the *libri de materia medica* of Dioscorides had made its appearance as early as 1478 and a Greek edition appeared at about the same time in Cologne.

Although the Romans were good observers of natural objects and phenomena, and equally good compilers of the knowledge of their own period and of previous periods, they did not, in general, penetrate into the secrets of nature. Neither did they do much to the stock of knowledge handed down to them. The natural sciences and medicine were, therefore, but little advanced by them.

With the decay of Greek and Roman culture and the long night in the history of civilization that followed, many of the earlier achievements in the arts and crafts were lost. At the close of that period which we now designate as antiquity, birth was given to a new civilization. Strange as it may seem the Mohammedans were the forerunners of this new period although they are reported to have destroyed the transmitted treasures of art and literature in the belief that the Koran contained all human wisdom. The Arahians themselves, however, contributed but little to this Mohammedan period of civilization. This had its roots in the Alexandrian school, the spirit of which was imparted to the later conglomerate of Mohammedan peoples through the Syrians and Persians and their languages, also through the Greeks of Asia Minor. This Mohammedan empire, as it were, included practically all of the peoples subjugated during the eighth and ninth centuries. Westward it extended as far as the gates of Hercules, or Strait of Gibraltar; to the East as far as the sea of darkness, as the Arabs called the Indian Ocean. They succeeded in converting the subjugated peoples to the Mohammedan religion. In as much as the Koran was

A more recent edition of the *Materia medica* of Dioscorides, which was used in connection with this book, is the one edited by Professor Curtius Sprengel. It appeared in Leipzig in 1829 as a part of the Kuehn Collection, namely the *Medicorum græcorum Opera quæ extant*, of which it constitutes volume 25. Of the two parts the first contains the *De Materia medica libri quinque*, the second part *Liber de venenis eorumque precautione et medicatione* (pp. 1—338) and *Commentarius in Dioscoridem* (pp. 340—675).

¹) Plinii Secundi *Naturalis Historiæ libri XXXVII*. Recognovit atque edidit Ludovicus Janus. Lipsiæ 1859.

Most of the references to Pliny made in this book refer to the two-volume edition of Littré, Paris 1877.

²) Clandii Galeni *Opera omnia*. Editio Kuehn, in twenty volumes. Lipsiæ 1821 1833. Worthy of special mention among these are the *De simplicium medicamentorum temperaturis et facultatibus libri XI*.

not only the spiritual but also the legal codex, Arabic language and script passed from country to country. Hence it became the language, not only of the faithful, but of the intellectual world, occupying the position held later by the Latin language during the Christian middle age.

Permeated by the conceptions of the Alexandrian school, the Arabs revived the study of the natural sciences in the ninth century. Mathematics, astronomy and medicine were rapidly developed. With their tendency to faith in the miraculous, alchemy and magic developed with the natural sciences and played an important role in the theory of transmutation of the metals and in medicine. The philosopher's stone and a universal medicine, the faith in which permeated human society for centuries, were to banish all misery and disease from this world.

Above all it was Geber¹⁾ (Djafir), one of the most influential and prominent scholars of his time, who developed this theory and established a firm faith in it which lasted for centuries. During the period when Bagdad, Bassora and Damascus were the principal centres of commerce, no people was more skilled and more productive than the Arabians in the arts and trades and also in natural science. Their commercial relations extended to almost all known countries, and the use and knowledge of Eastern spices and aromatics was greatly fostered by them, as was also the practice of medicine.

With the development of the traditional knowledge, the Arabians also fostered the process of distillation in connection with the hermetic art²⁾. As early as the fourth century, the

¹⁾ Gebri *Summa perfectionis magisterii*. Ex bibliotheca vaticana exemplari. Gedani 1682. Lib. IV. p. 156—178. — *Alchemia: Gebri Arabis libri excud.* Joh. Petrius Nucrembergensis. Bernæ 1545. Lib. 2. cap. 12. — Torbert Bergmann, *De primordiis chemiæ*. Upsala 1779. § 3D and § 4C. Editio Hebenstreit. Lipsiæ 1787.

In addition to the works of Geber originally written in Arabian, a number of other works in Greek and Latin were until recently attributed to him. However, M. Berthelot has revealed the apocryphal character of these writings (*Introduction à l'étude de la chimie des anciens et du moyen-âge*, Paris 1889, also *Revue des deux mondes*, September 15. and October 1. 1893). Among these are the *Summa perfectionis magisterii* which appears not to have been written before the middle of the fourteenth century.

²⁾ Hermannus Conringius, *De hermetica Aegyptiorum vetere et Paracelsiorum nova medicina libri duo*. Helmstedt 1648. Lib. II, cap. 4.

Greek scholars Synesios of Ptolomais¹⁾ and Zosimos of Panopolis²⁾ had described the distilling apparatus and methods of the Egyptians. Aëtius of Amida, a physician and writer who lived in Constantinople during the beginning of the sixth century, also described the preparation of empyreumatic oils by downward distillation (*Destillatio per descensum*)³⁾. This as well as the upward distillation (*Destillatio per ascensum*) are reported by Geber. According to Porta's *De destillatione* of 1567⁴⁾ and other writers of the sixteenth century the Arabian physicians and alchemists introduced the condensing tube (*Serpentina*) for the better cooling of the distillate, and a kind of fractionation for the distillation of wine⁵⁾.

Through the Arabians the medical and alchemistic knowledge of their times, also the mysticism of the hermetic⁶⁾ art were transmitted to southwestern Europe. They were most prominent in the establishment and advancement of the theory of the transmutation of the metals, a theory which held sway for many centuries; also of the preparation of a quintessence

Torbert Bergmann, *Historiæ chemiæ medium seu obscurum ævum*. Editio Hebenstreit. Lipsiæ 1787. Vol. 4.

Schmiedeknecht, *Geschichte der Alchemie*. Halle 1832. p. 85 et seq.

¹⁾ Synesii *Tractatus chymicus ad Dioscoridem*. In Fabricii *Biblia græca*. Tom. 8.

²⁾ "Et quid plura moramur? Unus Zosimos Panopolites libro *ὑπερὸν τῶν αἰώνων* loculente ad oculos nobis sistit antiquorum illa vasa destillationibus accommodata; postquam enim jussisset candidatos artis id agere ut ipsis ad manus esset *ἡ ἀρχαία καὶ ἀληθὴς ἀποκατάστασις τῆς κατὰ τὴν ἀρχαίαν ἀποκατάστασιν*, mandassetque *ἐν τῇ ἀρχαίᾳ τῇ ἀποκατάστασιν* *ἡ ἀρχαία καὶ ἀληθὴς ἀποκατάστασις*, ita ut *ἐν τῇ ἀρχαίᾳ τῇ ἀποκατάστασιν* *ἡ ἀρχαία καὶ ἀληθὴς ἀποκατάστασις* tandem, ut clarius sese explicet, ipsas vasorum figuras appingit, quarum nonnullas licet rudiori manu exaratas ex bibliotheca regis christianissimi, et illa D. Marci Venetis, libuit hic in gratiam curiosorum adjicere." (O. Borrichius, *Hermetis Aegyptiorum et chemicarum sapientia*, ab Hermann Conringii *animadversionibus vindicata*. Hafniæ 1674. pag. 156.)

Detailed statements concerning Zosimos' account on distillation are also found in Höfers *Histoire de la chimie*. 2. Edit. 1866. Tom. 1. pp. 261—270.

³⁾ Aëtii *libri octo antiquæ præparationis, Libri medicinales sedecim*. Editio Aldina 1533. fol. 10. - See also footnote 4, p. 68.

⁴⁾ See p. 44, footnote 7.

⁵⁾ See the illustration on p. 41.

⁶⁾ The designation spagyric art, from *σπᾱγός* and *ἀγνῶσις*, came into use during the time of Paracelsus, viz. in the first half of the 16. century.

from organic nature; and that of the much-sought *lapis philosophorum*. It was through this dogma that entered the medical and theosophic realm of the middle ages, and through the search for these imaginary phantoms that the Arabians laid the foundation for the acquisition, by empirical methods, of practical chemical knowledge, of numerous facts and products. These in turn served as building stones with which the later chemical structure was erected. In the course of the ninth and tenth centuries the Arabians also established the universities at Cordova, Seville and Toledo. As centers of learning and research, these institutions were visited by seekers of knowledge from all countries for the purpose of studying medicine, magic and necromancy.

Arabian medicine, and with it the art of distillation and the literature thereon, attained their greatest development during the period from the eighth to the eleventh centuries. However, but little definite information has come down to our own time concerning the numerous writers whose works have been perpetuated in their entirety or only in part. As a matter of fact, many of the works attributed to them are apocryphal and the real authors are not known with any degree of certainty. Not only is there a variation of one or more centuries in the dates attributed to them, but the opinions of historians concerning them is oftentimes contradictory.

The Arabian writings which are of greatest importance in the documentary study of the history of distillation begin with the works of Geber about the ninth century. From the twelfth century on, the Arabian alchemists devoted themselves exclusively to the transmutation of the baser metals to the nobler ones, to the search for the *lapis philosophorum*.

It was during this earlier period of almost four centuries, devoted largely to medical research, that the Arabians acquired considerable skill in the art of distillation and the preparation of distilled waters, of several oils and of alcohol, a skill that was later lost in large part. Medical and alchemistic literature reveal this knowledge of distillation, distilling apparatus and distillates.

Since the time of the Egyptians it was Geber, whose fragmentary writings reveal for the first time a fair knowledge of distillation, both of the dry distillation and of the distillation

with water. He used apparatus made from glass, also from glazed earthenware. Next to Geber, Mesue the younger was probably the earliest of the more important medical writers. He lived somewhere between the eighth and tenth centuries. It is not improbable that there were several authors bearing this name, also that other writers published their works under this famous author's name, and that in later periods an exchange of names and writings may have taken place.

The most important work of Mesue is his *Antidotarium seu Grabaddin medicamentorum compositorum libri XII*. For many centuries it was a medical authority. In the twelfth chapter, *De oleis*¹⁾ the method of preparation of oils is described. Most of these are aromatized fatty oils. However, the oils from juniper wood and bitumen are directed to be prepared by dry distillation which process is described in detail. According to Bergmann, Mesue is supposed also to have known distilled oil of rose and amber oil.²⁾

Other medical authors of this period reveal a knowledge of distilled waters and oils and their uses. Thus Ibn Khaldun³⁾, who lived during the ninth century, mentions that distilled rose water was an important article of Persian commerce during the eighth and ninth centuries. Nonus Theophanes,⁴⁾ who during the tenth century was physician to emperor Michael VIII in Constantinople, recommended rosewater as a medicinal agent. The Syrian physician Scrapion (Janus Damascenus) who lived in the ninth century, also Avenzoar⁵⁾ who lived about a cen-

¹⁾ Editio Veneti 1502, fol. 80.

²⁾ "Mesue medicamentorum plurimorum inventionem magnam famam et nomen evangelistæ pharnacopolarum consecutus est; durante hodie nunc in officinis nostris compositiones nonnullæ, quæ ille primus descripsit." — "Mesue aquam destillatam rosarum, oleum ex succino et lateribus tamquam veteribus nota memorat". (Torbert Bergmann, *Historiæ chemiæ medium seu obscurum ævum*. Editio Hebenstreit. Lipsiæ 1787, p. 7).

³⁾ *Notices et extraits des manuscrits de la bibliothèque impériale à Paris* 1862. Tom. 19, p. 364.

⁴⁾ Nonus Theophanes, *Prefatio ad Synesii De febribus*. Editio Bernardi. Amstelodami 1749. Cap. 28, p. 112.

⁵⁾ Liber Theizir Dahalmodana Vahaltadabir *Proœmium Averrhoi Cordubensis* ab Jacobo Hebræo. Anno 1281. Colliget Veneti 1553. Liber 7. fol. 1. Lib. 5. cap. 9. fol. 44.

tury later and who was physician to the Caliph Ebn Attafin of Morocco, used rose water as an eye-remedy and rose oil sugar as an internal remedy. In the medical writings of Abn Dschafar Aehmed, an Arabian physician of the eleventh century, which were translated into Greek by Synesius of Constantinople, rose water, rose oil and camphor are mentioned among the current remedies.¹⁾

While Geher was the first, and also the most important Arabian writer who was acquainted with distillation, the writings of Albueasis, who lived three centuries later, reveal such an exact knowledge of the subject, that the assumption seems justified that distillation was largely practiced by the Arabians. The *Liber servitoris*²⁾ of Albueasis contains a very clear description of the process of distillation which Torbert Bergmann, the

¹⁾ Synesius, *De lehribus*. Editio Bernardi. Amstelodami 1749. p. 58 and 240.

²⁾ A number of the works of the Arabian physicians and alchemists of this period have been preserved in a collective edition published in Venice in 1501. In addition to the principal work of Mesue and the *Antidotarium* of Nicolas and commentaries on the same, this folio contains several works of contemporaries. The titles of the individual works are herewith given: —

"Uni Joannis Mesue Liber de consolatione medicinarum simplicium et correctione operationem ærum canones universales: cum expositione preclarissimi medici magistri Bondini de lentiis feliciter incipiunt." (fol. 2-31.)

"Additiones Petri Apponi medici clarissimi, et Francisci de Pedemontium." (fol. 31-90.)

"Joannis Nazareni filii Mesue Grabaddin medicinarum particularium incipit." (fol. 91-266.)

"Antidotarium Nicolai cum expositionibus, et glossis clarissimi magistri Platearii." (fol. 267-293.)

"Expositio Janis de Santo Amando supra antidotarii Nicolai incipit feliciter." (fol. 294-330.)

"Tractatus de synonymis quid pro quo." (fol. 331-334.)

"Liber Servitoris seu libri XXVIII Bulchasin Ben-aberazerin: translatus a Simone Januensi: interprete Abraamo Judeo Tortuosiensi." (fol. 334-345.)

"Uni Saladini de esculo Servituti principis Tarenti physici principalis compendii aromatorum opus feliciter incipit." (fol. 346-354.)

Quæ omnia supradicta hic finem habent ad laudem dei. Veneti Impressa anno Domini 1502, die 23. Junii.

The oldest individual editions of some of these treatises date back as far as 1471, hence to the invention of the printing press.

Swedish chemical historian, regards as one of the first and best.¹⁾

The distillation of water, of acetic acid, and of alcohol is described in the following words in the writings of Albucasis.²⁾

"Modus faciendi aquam rosatam. Operatio ejus est secundum quatuor modos . . . Sed modum operationis ejus, quæ fit cum aqua et inge Ilgnorum, ego monstrabo secundum formam, quam faciunt reges Aharach. Et hic est modus ejus. Facias berchile parvum in domo ampla, cujus fundus et latera sint ex plumbo, adeo discreta simul solidata, ut aqua non possit egredi ab eo: et facias tibi coopertorium ex vitro cum sagacitate, vel ex terra vitreata, et in eo forma secundum formam vasorum distillationis, vel secundum quantitatem magnitudinis berchilis, vel parvitatem ejus, secundum voluntatem tuam faciendi multam, vel paucam aquam rosatam. Deinde pone ollam magnam ex ære vel cactabum post parietem, juxta quam posuisti berchile secundum formam ollæ balnei, et construe eam super furnum, et berchile sit constitutum super furnum, inferius ab olla, ita quod applicet de calore ignis berchilis ad ollam. Et facias caminam cum foraminibus, per quæ possit fumus extra domum egredi, ita quod fumus totus e donio egrediatur, et non noceat aquæ rosatæ. Deinde imple ollam ex aqua, quæ sit in puteo facto juxta ollam, sicut est puteus balnei, et accende ignem sub ea, quousque bulliat aqua bene. Deinde dimitte venire aquam per canale, quod fecisti per discretionem ad berchile, deinde pone aliam aquam frigidam in ollam ex puteo, sicut in olla balnei sit et constitue in berchile canale, per quod egredere cucurbitas sive ventres, et sint vasa destillatoria in foraminibus berchilis; et stringe cum panno lini discrete, ita quod bene sedeant in foraminibus suis, et vapor aquæ non egrediatur extra. Similiter, et capita eorum stringes cum panno lini . . . Et operatio ejus quæ sit in terra nostra est servior et brevior, quam illa, quam dixi. Et est, quod accipias ollam ex ære sicut est illa tinctorum, et pone post parietem, et pone super eam coopertorium discrete factum, cum foraminibus in quibus ventres ponuntur, et pone in eo ventres cum sagacitate, et postea imple ollam aqua . . . Operatio ejus sine aqua et cum igne carbonum est, quod facias furnum quadrum, aut rotundum, et habeat coopertorium superius, super quod stabunt ventres ex terra vitreata, ut possint sustinere ignem, et quando accendentur carbones, et incipiet aqua rosata destillare, claude os furni, et dimitte foramina aperta, per quæ fumus egrediatur."

¹⁾ "Describuntur in hoc libro præter alia, distillationis modus triplex, aquæ, acetii et vini destillatio, alembici et cucurbitæ quatuor generum, vitrei, fictiles vitro incrustati, plumbei et ærei commemorantur." — Torbert Bergmann, *Historia chemiæ medium seu obscurum ævum*. Editio Hebenstreit. Lipsiæ 1787.

²⁾ *Liber Servitoris seu libri XXVIII Bulchasin Ben-aberazerin: translatus a Sinione Januensi: interprete Abraamo Judeo Tortuosiensi 1471.* — Editio Veneti 1502. fol. 339b, 341b und 342.

"Modus alius cui vult destillare paucam aquam. Accipe ollam ex ære, et imple eam aqua, et pone super lanem ignem, et pond super os ejus cooperatorium perforatum foraminibus duobus vel tribus vel pluribus aut paucioribus ventribus, secundum quod poterit capere coopertorium ollæ, et sint ventres ex vitro . . ."

"Modus albificandi acetum . . . Construc athanor simile illi, in quo destillatur aqua rosacea, at superpone ei vas destillatorium ex vitro, vel ex terra vitreata et imple tres partes ex aceto bono, et quarta pars vasis superius sit vacua, ne cum ebullierit acetum, effundatur extra; deinde operi vas cum vase aliquo superius, sicut novisti habente nasum, sicut sit in aqua rosacea; et fac ignem levem non fortem, nam si esset fortis, non fieret acetum album tantæ albedinis, et est necesse, ut acetum, quod distillatur, sit ex uvis albis, clarum, et acre, in fine acedinis, quia tunc distillatur album et purum."

"Secundum hanc disciplinam potest destillari vinum, quod vult ipsum destillare."

During the period from the eighth to the twelfth centuries medicine and materia medica were greatly advanced by the Arabian scientists. The method of preparation of medicaments by subjecting vegetable and animal substances to distillation was in common vogue at this time. Hence the art of distillation was one of the principal methods of technique described in medical as well as in alchemistic treatises. It is not likely, therefore, that the separation of oils from the distillates of plants and plant products rich in oil, should have escaped the observation of the eager experimenter. Inasmuch, however, as the distilled waters were regarded as the bearers of the "subtle" ingredients of the drugs, any oil separating from the aqueous distillate may have been regarded as a more gross product and hence may have received but little attention. Moreover, little was known concerning the character of oils, whether fatty or aromatic. So much is certain, that the literature of the period reveals the fact that but few volatile oils found application.

From the eleventh century on, the desire for gain and the search for the *lapis philosophorum*, i. e. the conversion of the baser metals into nobler ones predominated more and more. Hence Arabic science went astray and pursued the illusory speculations of the hermetic art. After the middle of the 12. century there do not appear to have been any great Arabian physicians and scientists. With the conquest of Bagdad by the Mongols in 1258, Arabic dominance ceased and with it its spiritual leadership. For a time Arabian culture lingered in

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The distillation of water, of acetic acid, and of alcohol is described in the following words in the writings of Albu-casis.²⁾

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¹⁾ "Describuntur in hoc libro præter alia, distillationis modus triplex, aquæ, acetii et vini destillatio, alembici et cucurbitæ quatuor generum, vitrei, fictiles vitro incrustati, plumbei et ærei commemorantur." — Torbert Bergmann, *Historia chemiæ medium seu obscurum ævum*. Editio Hebenstreit. Lipsiæ 1787.

²⁾ *Liber Servitoris seu libri XXVIII Bulchasin Ben-aberazerin: translatus a Sinione Januensi: interprete Abraamo Judeo Tortuosiensi 1471.* — Editio Veneti 1502. fol. 339b, 341b und 342.

pharmacy shared as well as chemistry. However, this phase in the process of the evolution was a very gradual one, accompanied by ups and downs in the course of four centuries.

As has already been pointed out (p. 17) the distillation of wine was probably known to the Indians and Egyptians. The oldest, definite, documentary evidence, however, is to be found in the *Liber ignium ad comburendos hostes*, an apocryphal treatise of the eighth century attributed to a mythical author, viz. Marcus Græcus. The directions for making a "water that will burn" are as follows: "Take black wine, add finely powdered sulphur, tartar and common salt and place all into a distilling vessel. Upon distillation you will obtain a water that will burn". The texts of this treatise found in the library at Paris and in the University Library at Munich contain the following additional statement. "The peculiar property of this burning water can be demonstrated in the following manner: Dip a strip of linen into this water. When you ignite it a large flame will result. If you moisten a finger with this water and approach the fire with it, the finger will burn like a candle without being injured."

In the same treatise Marcus Græcus also describes the distillation of turpentine oil from turpentine in an alembic.¹⁾ Supposing it to closely resemble the spirit of wine, he likewise designates it as *aqua ardens*. The synonymous designation of both distillates was maintained for a long time. A distinct difference between the two was possibly not recognized before the beginning of the seventeenth century. The designation "*Spiritus*" *terpentini*, however, is still in use at the present time.

Further mention of the distillation of the spirit of wine is found in treatise of the twelfth century. One of these references, viz. the one found in the "Key to Dyeing" may here be mentioned. The treatise itself is a collection of technical formulæ, in part of Greek, in part of Roman origin, with Arabic addenda. The reference pertaining to spirit of wine reads as follows: "When strong wine is heated with salt in a suitable vessel, a combustible water results, which burns without destroying the substance on which it burns."

¹⁾ "Recipe terebinthinam et destilla per alembicum aquam ardentem quam impones in vino cui applicatur candela et ardebit ipsa." (*El libro ignium ad comburendos hostes.*)

With the downfall of Arabian civilization, the art of distillation as practiced by the Arabians appears largely to have been restricted to the distillation of alcohol. The better kinds of distilling apparatus that had been made by the Arabians, the cooling vat and the spiral tube (*serpentina*) which had been introduced by them, had been preserved and were revived for the production of the spirit of the wine, the "burnt" water.

Among the "burnt" waters it was the "spirit of wine" which was early appreciated because of its animating effect. Being regarded as representing the highest potency of the wine, it found ready application in medicine. Thus the Cardinal Vitalis de Furno of Basel, and Bishop of Albano, in the beginning of the fourteenth century declared that spirit of wine was a panacea.¹⁾ Bishop Albertus Magnus of Regensburg (Albert von Bollstaedt, born 1193, died 1280) occupied himself with the distillation of wine, which process he described carefully in his writings. It was possibly Arnoldus Villanovus (Arnold de Bachuone, born 1235, died 1312) who first introduced the Arabic term "alcohol" into German nomenclature. In his treatise *De conservanda juventute* he describes its preparation in the following words: "Burnt water also known as *aqua vitæ*, is obtained by the distillation of wine or wine yeast. It is the subtlest portion of the wine. Some say that it is "the everlasting water", also that, because of its sublime method of preparation, it is the "gold water" of the alchemists. Its advantages are well known. It cures many diseases, prolongs life and hence deserves to be known as *aqua vitæ*."²⁾

With the distillation of turpentine oil³⁾ and rosemary oil,⁴⁾ Villanovus was well acquainted. His *oleum mirabile* consisted essentially of an alcoholic solution of rosemary and turpentine oils. This mixture was sold by him or his disciples as an external remedy and later, with the omission of the turpentine oil, as a perfume. Under the designation "Hungarian water" it remained for centuries a much used specialty.

¹⁾ Vitalis de Furno, *Pro conservanda sanitate liber utilissimus*. Editio Mangel. Geneva 1531. Cap. 2, p. 12.

²⁾ Arnoldi Villanovi *Opera omnia*. Veneti 1505. *Liber de vinis*. p. 558.

³⁾ Arnoldi Villanovi *Breviarium practicæ, præmium in operis omnibus cum N. Taurelli in quosdam libros annotationibus*. Basilia: 1587, p. 1055.

⁴⁾ Arnoldi Villanovi *Opera omnia*. Veneti 1505. *Liber de vinis*. p. 589—590.

Raymundus Lullus (born 1234, died 1315) the most famous of the disciples of Villanovus, in the second half of the thirteenth century, described the distillation of the *aqua vitæ ardens* from wine and its refining. In order to obtain a liquid which would burn without leaving a moist residue, this rectification had to be repeated four times with the addition of burnt potash as dehydrating agent¹⁾. Of the alcohol he says: "*Est consolatio ultima corporis humani*"²⁾."

According to the alchemistic nomenclature of that period, the spirit of wine repeatedly rectified was designated as *Mercurium vegetabile*, *Argentum vivum vegetabile* and *Cælum philosophorum*³⁾. It was regarded as possessing certain powers in the transmutation of the elements and as representing a first step in the preparation of the *lapis philosophorum* and the *magisterium magnum*⁴⁾.

That "burnt wine" was a common article of commerce as early as the middle of the fourteenth century, also a beverage subject to abuse, becomes apparent from a collection of municipal ordinances of 1360 of the city of Frankfurt on the Main⁵⁾. The municipal council of Nuernberg, in the year 1496, prohibited the sale of "gebranntt weynes" on Sundays and holidays⁶⁾. In other German cities similar ordinances were issued: e. g. in Hussia in 1523, viz. under the Margrave Philipp⁷⁾, in Frank-

¹⁾ "Accipe vinum rubrum vel album, et sit de meliore quod poterit reperiri, vel saltem capias vinum, quod non sit acetosum quo vis modo, neque parum, neque minimum, et destilla aquam ardentem, sicut consuetum est per cannas brachiales aris et postea rectificata illam qualiter ad maiorem rectificationem." (Raymundi Lulli *Majoricæ*, *Philosophi acutissimi, de secretis naturæ vire Quinta essentia libri duo*. Anno 1541.)

²⁾ Raymundi Lulli *Testamentum novissimum*. In Manget's *Bibliotheca chemica curiosa*. Basilæ 1572. Vol. 11, p. 792.

³⁾ Euxonymi Philatri *Kostbarer theurer Schatz*. Vol. 1, p. 99.

⁴⁾ Raymundi Lulli *Testamentum novissimum*. In Manget's *Bibliotheca chemica curiosa*. Basilæ 1572. Vol. 1, p. 792 and 808.

⁵⁾ Henrici Christiani Senckenberg *Selecta juris et historiarum*. Francofurti 1734. Tom. 1. p. 44.

⁶⁾ J. Baader, *Nürnberg'sche Polizeiordnungen aus dem 13. bis 15. Jahrhundert*. p. 264.

⁷⁾ Joh. Beckmann, *Beiträge zur Geschichte der Erfindungen*. Leipzig 1786-1795.

furt a. M. in 1582 also in 1605¹⁾; likewise in Spain²⁾. Indeed the production of whiskey from cereals was regarded as an act displaying want of piety. Moreover, the adulteration of brandy with whiskey was punishable³⁾. On the other hand, brandy was introduced into Sweden in 1565, in the reign of Erich XIV, as an antidote against the plague⁴⁾.

About the middle of the sixteenth century a distinction was made in German apothecary shops between the stronger *Spiritus vini rectilicatus* and the weaker *Spiritus vini rectilicatus simplex*, also between both and brandy (*aqua ardens*)⁵⁾. During the second half of the sixteenth century Italy, more particularly Modena and Venice, appear to have supplied the more northern countries with spirit of wine⁶⁾.

The familiarity with which spirit of wine was used as early as the first half of the sixteenth century, becomes apparent from the "*Cælum philosophorum*"⁷⁾, by Philipp Ulstad, professor of medicine in Nuernberg. It was used for the preservation of meat, for the improvement of stale wine, for the extraction of spices and other parts of plants, hence for the preparation and utilization of alcoholic solutions of volatile oils, aromatic resins, and balsams.

From the thirteenth century on distilled aromatic waters were used more extensively as medicaments. The separation

¹⁾ Joh. F. Gmelin, *Geschichte der Chemie*. Göttingen 1797. vol. 1, p. 360.

²⁾ Christophoro a Vega, *De arte medendi*. Lugduni 1564. Pars 2. Cap. 2, p. 237.

³⁾ Joh. Beckmann, *Beiträge zur Geschichte der Erfindungen*. Leipzig 1786—1795.

⁴⁾ P. J. Bergius, *Tal om Stockholm för ar sedan och Stockholm nu fortiden*. p. 100—101. B. Bergius, *Tal om läkerheter*. T. 1, p. 32—33.

⁵⁾ Joh. Beckmann, *Beiträge zur Geschichte der Erfindungen*. Leipzig 1786—1795.

⁶⁾ Möhsen, *Geschichte der Wissenschaften*. 1810. p. 488—498.

⁷⁾ Alex. Tassoni *Pensieri diversi*. Venezia 1676. pp. 317 and 352.

A. Baccius, *De naturali vinorum historia et vinis Italix et conviviis antiquorum*. l. vii. acc. de facticiis vinis et cerevisiis, de omni vinorum usu. Roma 1596 and 1598.

⁸⁾ Philippi Ulstadii *Cælum philosophorum, seu liber de secretis naturæ, id est, quomodo ex rebus omnibus quinta essentia paretur*. Argentorati 1528 et 1562. Augustæ Trebocorum 1530 — Lugduni 1540 and 1553 — Parisii 1543 — Francofurti 1600.

of oils both at the surface and beneath the aqueous distillate was observed, but apparently received but little attention. Owing to the practice of using alcohol in the preparation of many of these aromatic waters, the oil must frequently have remained in solution wholly or in part. Thus, e. g. the plants or plant products to be distilled were moistened with wine or *aqua vitæ* before distillation; or, steeped in water, they were first allowed to undergo fermentation. Moreover, both alcohol and volatile oil were lost, in part at least, by submitting the plant products to a process known as circulation, a preliminary operation consisting of more or less prolonged digestion. In this manner inferior distilled or burnt waters were obtained.

Nevertheless, several of the more important experimenters and writers of that period knew and described volatile oils. In addition to the oils of turpentine and rosemary already mentioned, Arnoldus Villanovus¹⁾ and Raymundus Lullus²⁾ describe the distillation of oil of sage; Sancto Amando³⁾ that of bitter almond oil, oil of rue and oil of cinnamon; Saladinus of Aesculo⁴⁾ that of oil of rose and oil of sandalwood. The writings of their contemporaries also reveal a knowledge of these and other distilled oils without, however, making mention of their use in medicine or the arts.

The epoch-making inventions and discoveries of the fourteenth and fifteenth centuries wrought great changes in the natural sciences and their application. The discovery of the new world, made possible by the rediscovery of the compass, and the circumnavigation of Africa to the East Indies widened the horizon of the people. The period of the Renaissance and the Reformation assisted in doing away with the blind faith in authority, not only

¹⁾ Arnoldi Villanovi *Opera omnia*. Veneti 1505. *Liber de vinis*. fol. 589–590.

²⁾ Raimundi Lulli *Experimenta nova*. In Manget's *Bibliotheca chemica curiosa*. Geneva 1702. Vol. 5, fol. 829.

³⁾ *Expositio* Joannis de Sancto Amando *Supra Antidotarium Nicolai incipit feliciter*. In the same edition with the works of Mesue. Veneti 1502. fol. 228 and *Additiones* fol. 85, 86, 87.

⁴⁾ *Compendium aromatorum* Saladini, principis Tarenti dignissimi, medicis diligentis, correctum et emendatum. Bononæ 1488. Editio Veneti 1471, 1488 and 1502. fol. 349b.

in theology but in the natural sciences as well, more particularly in medicine and alchemy. The founding of universities to the north of the Alps during the fourteenth and fifteenth centuries, and the invention of printing with type toward the close of the fifteenth century, which followed wood engraving invented in the previous century, assisted largely in revealing anew the literary treasures of the past.

Up to this time all treatises had to be multiplied in manuscript form. Presumably, therefore, many discoveries were known only to small circles and by no means to all scientists and investigators. No doubt, much disconnected work was done by some that was long known to others. As a result, the first discovery e. g. of a process or product, has never been traced. Moreover, as a result of tradition from one generation to another, from one country to another, much was lost¹⁾ even though recorded in manuscripts. Or, if inadequately recorded, it was not understood. Furthermore, it was the practice among alchemists, to use an allegorical language for the purpose of surrounding their treatises with a mysticism suited to their spagyric art and science. Hence these treatises were comprehensible only to the initiated. There was still another reason why the seeking for the *lapis philosophorum* was surrounded by a mystic language. It was done partly to cover up the alchemist's own uncertainties, partly to render it more difficult for others to find the much coveted solution to the secret. At the same time each adept, experimenting in his own secluded laboratory, supposed that the others already possessed the secret.

It was with the gradual introduction of printed books during the beginning of the sixteenth century, that the treatises of the past became more and more the common property of those versed in science and reading. Up to this time, and even in later times, much that had been known to and practiced by individuals, was lost and had to be rediscovered.

This is true of the methods of distillation and of the apparatus used. Thus the apocryphal treatises of antiquity seem to show that the early method of primitive distillation was discovered by peoples widely separated both as to locality and time. Frequently

¹⁾ Compare e. g. the quotation from Adam Lonicer on p. 49.

there is no record of the direct transmittance of the art from one people to another. Wherever such transmittance may have taken place, it appears to have led less to a technical accomplishment than to a general stimulus.

In the history of special peoples, cultural stages are found, in the evolution of their trades as well as in their literary productions, which are fundamentally related both to their material development and their political changes. Hence, the former can be fully understood only when considered in connection with the latter. Material and national welfare appear in history as a rule contemporaneously with intellectual and industrial achievement.

As to the discovery of natural products, the knowledge and separation of their components, and the utilization of these discoveries in *materia medica* and medicine, a new epoch was inaugurated, at the time of the reformation, by Paracelsus and others. With it the practice of the art of distillation was again conducted into proper channels. Thus it was made serviceable to *materia medica* and later to the trades. As a result there were produced in the course of time, an ever increasing number of important products. In addition to the production of alcohol, there should be mentioned the distilled aromatic waters which were highly prized and used in medicine for nearly three centuries. These were followed later by the distilled oils.

In the course of the twelfth and thirteenth centuries the art of distillation, which had been developed first by the Egyptians and later by the Arabians, was practiced but little.¹⁾ Hence, the methods and apparatus had been forgotten and had to be rediscovered. This reintroduction and rediscovery was furthered toward the end of the thirteenth and the beginning of the fourteenth centuries by the principal alchemists and physicians of that period, viz. by the Cardinal Vitalis de Furno of Basel (died 1327), the Bolognese teacher Thaddeus (Taddeo Alderotti, born 1215, died 1303), Arnoldus Villanovus (Arnold de Bachuone of Villeneuve or Villanova, born 1235, died 1312) and Raymondus Lullus (born 1235, died 1315). With this period, the distilling

¹⁾ Compare pp. 17, 24 and 26.

apparatus again found their way into the work shops of physicians and alchemists, became increasingly important and were accordingly improved. As the art of pharmacy was separated more and more from that of medicine, and as apothecary shops were established in larger numbers, the art of distillation gained admission to the laboratories attached to these shops. Carefully nursed, the art of distillation here developed into an important industry viz. that of the production of volatile oils.

As a result, the progress made by the art of distillation henceforth is primarily to be sought in the literature on materia medica, as this had already been the case in the earlier Arabian medical treatises, viz. the antidotaries, e. g. the Grabaddin and other treatises. With the printing of books the number of medical treatises increased. Although they afford information concerning the time of introduction of drugs and distilled waters, and hence are of permanent interest to the student of materia medica, they are less satisfactory as sources of information concerning the production and introduction of distilled oils. Nevertheless, even for this purpose they constitute almost the only available literary sources.

The numerous works that came under consideration may be classed into three groups of equal importance: the antidotaries and the later dispensatories; the treatises on distillation which occupied a prominent position from the close of the fifteenth century to the close of the sixteenth century; and the price ordinances of various cities for spices and drugs which had come into use about the same time.

As already pointed out, the term "distilled" oils should not necessarily be interpreted in the same sense as we use it to-day. The ancients had already known how to obtain fragrant oils by boiling seeds, fruits and other parts of plants with water also by cold and warm expression. These were used in the preparation of aromatic oils and ointments. However, all exact knowledge concerning the nature of these oils was wanting. Up to the seventeenth century this was equally true of the oils, obtained in all probability by the process of distillation, by the Indians, the Egyptians and later peoples. Neither was there any clear conception as to the distinction between fatty, expressed oils and distilled, aromatic oils.

Far into the middle ages, the designation "distillation" was used as a collective term for the preparation, according to the rules of the art, of plant and animal extracts and their supposed refinement. For this process of rectification, various methods and sources of heat also diverse utensils were used. The general term included such processes as maceration, digestion, straining, filtration, expression and sometimes even the processes of fermentation and decay.¹⁾ With the exception of turpentine or cedar oil those products mentioned in older literature as oils, or even as distilled oils, are to be regarded as fatty oils which have been aromatized and which were used for medicinal purposes and as unguents.

Whether the oils of rose, andropogon, and calamus, mentioned in the Ayur-Veda as distilled oils, were such in the modern sense of the term, can not be decided. The same doubt exists as to the oils of spike, rosemary and sage, as well as of other oils of later writers. As has already been pointed out, the art of distillation, known at an early period, may have fallen into disuse and have been forgotten.

Although, in all probability, the Indians, the Babylonians, and especially the Egyptians were acquainted with the art of distillation, also with volatile oils, a sharp distinction between true distilled oils and aromatized fatty oils does not seem to have existed at the beginning of the Christian era. The latter were used principally for the purposes of cleanliness and well-being, also in religious rites, such as anointing and embalming. Hence the simpler process of aromatizing fatty oils may have been preferred by the priests. In accordance with this assumption are the directions for the preparation of rose oil, a supposedly "distilled oil" by Dioscorides,²⁾ copied by Pliny³⁾ during the first century.

¹⁾ Compare p. 33.

²⁾ Petri Andreae Matthioli Opera quæ extant omnia: hoc est Commentarii in sex libris Pedacei Dioscoridis Anazarbei de materia medica. Post diversarum editionum collationem infinitis locis aucti. De ratione destillandi aquas ex omnibus plantis; et quomodo genuini odores in ipsis aquis conservari possint. Veneti 1544 — Basilie 1565. Liber I, cap. 53.

³⁾ Plinii Secundi Naturalis historiæ libri. Liber XIII, cap. 2.

"Five and one-half pounds of bruised *Juncus odoratus* (probably *Andropogon Schœnanthus*, L.) are boiled with 20 1/2 pounds of oil with constant stirring. Into the strained liquid the floral leaves of 1000 roses free from moisture are pressed with hands that have been anointed with fragrant honey. After standing over night the oil is expressed. After all impurities have subsided the oil is decanted into another vessel and the expressed rose petals are treated with a second quantity of 8 1/2 pounds of fresh oil. After standing for a day the oil is again expressed. This is the *Oleum secundarium*. If a third and fourth maceration are to be made, oil is again poured on the roses and as often expressed. Thus the *Unguentum primum, secundarium, tertium and quartum* are prepared.

The vessel, however, must each time be covered with a film of honey. If the maceration is to be repeated a second time, a like quantity of fresh rose petals free from moisture is immersed into the oil first expressed. The mixture is kneaded with hands anointed with honey. In like manner the oil is expressed a second, third and fourth time, and each time rose leaves free from the calix are added. In this way the oil becomes much stronger. Up to a seventh infusion the same oil can be used but no farther. Furthermore, the oil should be carefully separated from the aqueous juice, for the oil will spoil if any of this juice remains with the oil."¹⁾

A single distilled oil, however, was known as early as the first century, viz. turpentine oil. Its peculiar method of preparation, as well as the apparatus used, are described in the chapter on the "History of the methods of distillation and distilling apparatus."

Taking into consideration the early acquaintance of distilled oils by ancient peoples and later by the Arabians, it can scarcely be doubted that the oils which must have separated on the surface of "burnt waters" during the process of distillation of aromatic plants and spices, practiced so diligently during the fifteenth century, could have escaped attention. Being regarded as coarser particles they probably received little attention and hence found no application, for the therapeutically active waters alone were the only object of the distillation. Thus, while it is known from other sources that a number of distilled oils were known, one of the oldest price lists of drugs and spices, viz. the one of the city of Frankfurt-on-the-Main of 1450 does not mention a single distilled oil.²⁾ However, a similar list of the same city

¹⁾ From the German translation of the works of Dioscorides in *Trommsdorffs Journ. der Pharm.* 11 (1803), 112.

²⁾ *Ita sunt nomina medicinarum simplicium sive materialium quæ ad apothecam requiruntur, In genere et in specie.* Published as a separate by Prof. F. A. Flückiger in 1873 with the title "*Die Frankfurter Liste.*"

for the year 1582 mentions forty-two volatile oils,¹⁾ and a further list of 1587 fifty-nine such oils.²⁾

At the close of the fifteenth century the art of distillation and the distillation of aromatic waters were greatly advanced by the first larger treatise on distillation, viz. the *Destillirbuch* of the Strassburg physician Hieronymus Brunschwig (born abt. 1450, died abt. 1534) which was published in the year 1500. The book is illustrated by numerous cuts of stills and utensils, likewise of the plants used in the preparation of "burnt waters." In some editions, these cuts were colored. The title pages of the two voluminous folios, which were printed in 1500 and 1507, are of special interest in the history of distillation. Reduced facsimile reproductions will be found on pages 40 and 41.

The first volume contains 212 paged leaves (424 pages), the second volume 344 leaves (688 pages). The work is devoted mainly to a description of the methods of preparation of the much lauded³⁾ "burnt waters," accompanied by directions for their use and an explanation of their action. In addition it contains directions for the preparation of numerous "burnt

¹⁾ *Register aller Apothekischen Simplicien und Compositen, so in den beiden Messen zu Frankfurt am Main durch Materialisten, Kauffleut, Wurzelträger, Kräntler und durch die Apotheker dasebst verkauft werden. Frankfurt-on-the-M. 1582.*

²⁾ *Reformatio oder ermente Ordnung der heilig Reichstadt Frankfurt a. M., die Pflege der Gesundheit betreffend. Den Mediciis, Apothekern und Materialisten zur Nachrichtung gegeben. Darneben den Tax und Werth der Arzneien, welche in den Apotheken allda zu finden. 1587.*

³⁾ The praises of the "burnt waters" were sung in prose and verse. Of the more prominent writings the following may be mentioned: *Loblied vom branntewein. Wem der geprant wein nutz sey oder schad. un wie er gerecht oder lalschlich gemacht sey. getruckt zu Bambergk von marxen Ayrrer. Undt Hannsen Pernecker in dem Zinkenwerd. in 1493 jar.* Reprinted in: Joh. Beckmann, *Beiträge zur Geschichte der Erfindungen.* Leipzig 1786 — 1795. Bd. II, Abt. 2, S. 277 — 288.

Michael Schrick, *Nützlich Büchlein von Kunst und Tugend der geprenten Wassern. getruckt am 28. Mai zu Nürnberg 1517.* New editions appeared in 1529 and 1601.

By Hubertus Barlandius in Mamur: *Epistola medica de aquarum destillatarum facultatibus.* Antwerpiae 1536.

By the Canon Remacius Fuchslius in Liège: *Historia omnium aquarum, quæ in commune hodie practlicantium sunt usu, vires et recta destillandi ratio.* Parisii 1542 — Veneti 1542.

Liber de arte distillandi de simplicibus.
**Das buch der rechten kunst
 zū distillieren die eintzigē ding**

von Hieronymo Bartschewyl Bürger vñ wundt arzt der Kaiserliche frey statt strassburg.



un getrukt durch den wohlgeachte Johannem grueningher zu Strassburg
 in den achte tag des megen als man zeit von der geburt Christi
 funfzehnbundert. Lob sy got. Anno 1500.

Fig. 1.

wines," elixirs of life, and simple and complex oils and balsams.

The lesser significance of the volatile oils becomes apparent from the fact that, in spite of the thorough knowledge and even practical experience of the author, but a single volatile oil, viz., the *oleum spicæ*,¹⁾ is mentioned and described in the first volume; and in the second volume only three additional ones, viz. *oleum terebinthinæ*,²⁾ *oleum ligni juniperi*³⁾ and *oleum rosmarini*.⁴⁾

In harmony with the knowledge of his times, are Brunschwig's views as to the nature and products of distillation. These are recorded in the following words in the introduction to the first volume of his treatise on distillation: "By distillation we understand nothing else than the separation of the subtle from the coarse, the coarse from the subtle, to render the fragile or destructible indestructible, the material immaterial, the bodily spiritual, the unhandsome handsome."

Ambiguous as were the conceptions of the nature of the constituents of the distilled parts of plants and their distillates, the technique of distillation, as becomes apparent from the next chapter, was well developed. For this very reason it seems strange that no mention is made of the observation of oils when such aromatic plant products as the umbelliferous fruits, the labiate leaves, juniper berries, cloves, cinnamon and other spices

¹⁾ Vol. I, fol. 72. „Das krut von de lateinischen *lavendula* und in tüt-scher zungen *lavender* genant, ist ein krut gemeiniglich yederman bekant, doch so ist syu zweingestalt, das ein von den lateinischen *spicula* und von den tüttschen *spic* genant, des vyl wachsen ist in dem lant provinz. Zu dyser zyt vuch in tüttscher nation glich dem geneinen *lavender*, von des blumen ein öl wird gemacht mit *putrisieren* un *dystillieren* genant *oleum de spica*."

²⁾ Vol. I, fol. 33, cap. 25. The rectification of turpentine oil by repeated shaking with water, rosewater or wine and final distillation is also described.

³⁾ Vol. II, fol. 289.

⁴⁾ Vol. II, fol. 52, also *oleum benedictum compositum* (fol. 53). Both are distillates from rosemary, turpentine, frankincense, mastix, ammoniacum, galbanum, oppopanax, cloves and cinnamon.

In Vol. I, liber 4, fol. 271—272 are likewise found descriptions for the preparation of a number of aromatic balsams (mixtures of volatile oils) by the distillation of mixtures of resins and spices to which turpentine oil has been added.

were subjected to distillation with water. Some of these non-aqueous "subtle" parts must have risen to the surface of the aqueous distillate, others must have collected at the bottom of the receiver, still others must have congealed. This silence is all the more remarkable since the specific object of distillation consisted in the separation and isolation of the volatile, the subtle, the *quinta essentia* from crude plant products and other natural objects; and since such oily separations had been known much earlier and had been mentioned in the literature of earlier periods.

The explanation for this lack of correct observation and the ambiguity of views as to the nature of the products of distillation is possibly to be sought in the change which the concept *quinta essentia* underwent in the course of time. Originally applied to the spirit of wine only,¹⁾ it was later applied to aromatic and empyreumatic oils, even to acetic acid²⁾ and other products of distillation.

The treatise of Brunshwig, which had received general recognition became the precursor of numerous other treatises on distillation which appeared in the course of the sixteenth century. They reflect the height of the faith which the medicine of that period had in the "burnt waters" and in the miraculous powers of the "most subtle" powers obtained from natural objects by distillation. Of the numerous treatises that made their appearance during the sixteenth century, the following are particularly worth mentioning, not only because of the fame of their authors, but also because of the influence which they exerted on the development of the art of distillation, and on a better understanding of the distilled oils, viz. those of

Philipp Ulstad,³⁾ physician and professor of medicine in Nuern-

¹⁾ *Liber de arte destillandi*. Vol. I, vol. 18 and 19. Brunshwig was well acquainted with the preparation of spirit of wine, not only by the distillation of wine, but also by that of fermented honey (vol. II, liber I, cap. 14 and 28), of fermented fruit juices (vol. II, cap. 18), also by the fermentation and distillation of herbs, roots and flowers (vol. II, cap. 19).

²⁾ *Ibidem*. Vol. II, cap. 26.

³⁾ Philipp Ulstadii *Cælum Philosophorum, seu liber de secretis naturæ tractatus, id est, quomodo ex rebus omnibus Quinta essentia paretur*. Argentorati 1543 u. 1528 — Augusta: Treboc. 1530 — Lugduni 1540 u. 1553 — Parisii 1543 — Francofurti 1600.

berg (at the beginning of the 16. century), Walter Hermann Reiff (Ryff,¹⁾ surgeon in Strassburg (in the first half of the 16. century), Pierandrea Matthioli²⁾ (born 1501 in Siena, died 1577 in Trient), Remaelius Fuchs³⁾ (born 1510 in Limburg, died 1587 in Brussels), Valerius Cordus⁴⁾ (born 1515 in Simshausen in Hussia, died 1544 in Rome), Conrad Gesner⁵⁾ (Euonymus Philatratus, born 1516, died 1565 in Zuerich), Adam Lonicer⁶⁾ (born 1528, died 1586), Giovanni Baptista della Porta⁷⁾ (born 1537, died 1615

¹⁾ H. Gualtherus Ryff, *Neu gross Destillirbuch wohl gegründeter künstlicher Destillation*. Francolurti 1556. (See p. 46.)

²⁾ Petri Andreae Matthioli Medici Casarii et Fernandi Archiducis Austriae Opera quae extant omnia: hoc est Commentarii in sex libris Pedacei Dioscoridis Anazarbei de materia medica. Post diversarum editionum collationem infuitis locis aucti: De ratione destillandi aquas ex omnibus plantis; et quomodo gemini odores in ipsis aquis conservari possint. Veneti 1544 -- Basiliae 1565.

³⁾ Remacii Fuchsii Historia omnium aquarum, quae in commune hodie practantium sunt usu, vires et recta destillandi ratio. Veneti 1542 -- Parisii 1542.

⁴⁾ Valerii Cordi Simesusii Annotationes in Pedacei Dioscoridis Anazarbei de materia medica libros quinque, longe aliae quam ante hac sunt emulgatae. Ejusdem historiae stirpium libri quatuor, et de artificiosis extractionibus liber. Tiguri 1540.

After the death of Cordus this work was published with additions (*Forti Germaniae*) and comments by Conrad Gesner in Zuerich. Several editions appeared in 1557, 1561 and 1583.

⁵⁾ Thesaurus Euonymi Philatri de remediis secretis; liber physicus, medicus et partim etiam chymicus et oeconomicus in vinorum diversi sapes apparatus, medicis et pharmacopolis omnibus praecipue necessarius. Tiguri 1552. Liber I. De destillatione ejusque differentiis in genere. Auctor est Conradus Gesnerus. Tiguri.

The German edition bears the following title: *Ein künstlicher Schatz Euonymi Philatri darinn enthalten sind viel heimlicher guter stuck der artzney, verteutscht durch Joh. Rud. Landenberger. Zürich 1555.*

⁶⁾ Adami Loniceri, *Der Arzney Doctor und weiland Ordinarii Primarii Physici zu Franchfurt am Meyn, Kräuterbuch und künstliche Conterfeyungen der Bäumen, Stauden, Hecken, Kräutern, Getriyde, Gewürzen und nützlichen Kunst zu destilliren*. . . . -- *Auf das allerfleissigste übersehen, corrigirt und verbessert durch Petrum Offenbachium, Ordin. Physicus in Franchfurt am Meyn.* Ulm, anno dei 1551, 1573 und 1589.

⁷⁾ Joh. Baptistae Portae Neapolitani, *Magiae Naturalis libri viginti, in quibus scientiarum naturalium divitiæ et deliciae demonstrantur. Jam de novo, ab omnibus mendis repurgati, in lucem prodierunt. Liber decimus: Destillat, destillata ad lastigia virium sustollit.* Ravennae 1565 -- Antwerpiae 1567 -- Neapoli 1589 -- Hanoviae 1619.

in Rome), Geronimo Rossi¹⁾ (Hieronymus Rubeus, born 1539 in Ravenna, died 1607 in Rome), C. C. Kunrath²⁾ (about the middle of the 16. century) and Jacob Besson³⁾ (about the middle of the 16. century).

Next to Brunschwig's treatise on distillation, those of Ulstad and Ryff are given priority. Not only were they frequently quoted by the later authors but the illustrations were invariably copied from the two volumes of Brunschwig and the next oldest treatise by Ulstad. Possibly Brunschwig and Ulstad obtained their illustrative material from Arabian sources.

About twenty-five years after the appearance of Brunschwig's treatise, the above mentioned smaller treatise on distillation by the Nuernberg physician Philipp Ulstad was used almost equally extensively.⁴⁾

It was published in Strassburg in 1526 and was shortly thereafter reprinted in Paris, Leyden, Frankfurt and elsewhere.

In 57 chapters the book supplies direction for the preparation of the supposed *Quinta essentia* by means of curious methods of circulation and distillation, which will be found mentioned in a subsequent chapter. The detailed explanations of the nature of the "fifth being" are merely a circumscription of the conventional ideas about distillation and the products of distillation already mentioned in connection with Brunschwig (p. 41). In

¹⁾ Hieronymi Rubi Ravennatis *De destillatione liber, in quo stillationum liquorum, qui ad medicinam faciuntur, methodus ac vires explicantur*. Ravennae 1580 and 1582, Basiliae 1581 and 1585.

²⁾ C. C. Kunrathii *Medulla destillatoria et medica, oder Bericht, wie man den Spiritus vini zur Exultation bringen sull*. Leipzig 1549.

³⁾ Jacobi Bessonii *De absoluta ratione extrahendi aquas et olea ex medicamentis simplicibus a quodam empirico accepta et a Bessonio locupletata, experimentis confirmata*. Tiguri 1559. -- A French edition appeared in Paris 1573.

⁴⁾ Philippii Ulstadii, patris nobilis *Caelum Philosophorum seu liber de secretis naturæ, id est: quomodo non solum e vino, sed etiam ex omnibus metallis, fructibus, radicibus, herbis etc. Quinta essentia, sive aqua vitæ, ad conservationem humani corporis educi debeat*. Argentor. 1526 and 1528 -- Lugduni 1540 and 1553 -- Parisii 1543 -- August. Treboc. 1553 -- Francofurti 1600.

The German edition bears the following title: *Dess Edlen und Hocherfahrenen Herrn Philippi Ulstadii von Nürnberg Büchlein von Heimlichkeiten der Natur, jetzund verdeutlicht*. Frankfurt am Mayn 1551.

The French translation which appeared in Paris in 1547 bears the title: *Le Ciel des philosophes ou secrets de la nature*. Paris 1547.

general, the aim of all of the cumbersome processes described by Ulstad, is the separation of the spirit of all substances from their earthy body. This *quinta essentia* in turn practically resolves itself either into a spirit of wine, more or less strong and aromatised by means of plant or animal products, or into a spirituous solution of metallic acetates (*aurum potabile*). All plant products, even apples, pears, cherries etc. further human blood, urine and other "subtle animal products" are subjected to cumbersome "digestion" and "circulation, i. e. to prolonged fermentation and putrefaction. Finally, "the spirit" is distilled and repeatedly rectified.

For the preparation of this "spirit" and that of a number of far famed *aquæ vitæ* the book provides exact directions.

Inasmuch as all of these distillates (*Quintæ essentia*) are strongly alcoholic, Ulstad had no knowledge of distilled oils and hence does not mention them in his treatise. This is true in spite of the fact that his *aquæ vitæ* are distilled from strongly aromatic spices and other plant products with wine.

The value which the works of Brunshwig and Ulstad have today in the history of distillation lies in the detailed and careful description of the apparatus and methods of distillation and the illustrations thereof.

About 56 years after the appearance of Brunshwig's "Destillirbuch" and 28 years after that of the first edition of Ulstad's *Cœlum Philosophorum*, Walter Reiff (Gualtherus Ryff),¹⁾ a surgeon in Strassburg during the first half of the sixteenth century, published a third treatise on distillation which was held in high repute for a long time. It has the following title:

New gross Destillirbuch, wohl gegründeter künstlicher Destillation, sampt underweisung und bericht, künstlich abzuziehen oder Separiren die fürnehmste destillirte Wasser, köstliche aquæ vitæ, Quintam essentiam, heilsame oel, Balsam und dergleichen vielgüter Abzüge. Recht künstlich und viel auff bequeme art dann hisher, auch mit bequemerem Zeug der Gefäss und Instrument, des ganzen Destillirzengs von Kreutern, Blumen, Wurzeln, Früchten, Gethier und anderen stucken, darinnen natürliche feuchte und Elementische kraft, einfach oder mancherley gestalt vermischet und componirt; durch H. Gualtherum Ryff, Medicum & chirurgum, Agentinensem, getruckt zu Frankfurt a. n. bei Christian Egenolff's selgen Erben im jar 1550.

This treatise is supplied with numerous colored illustrations of plants, also with cuts of furnaces and utensils used in distillation. Its succinct text reveals technical knowledge, as a result

¹⁾ He lived during the middle of the 16. century.

of which the book demanded considerable respect, was widely distributed, and repeatedly imitated. The personality of the author finds expression even in the preface in which he fearlessly criticises contemporary authors, more particularly Theophrastus Paracelsus,¹⁾ the reformer of medicine. The folio of 197 leaves (394 pages) is divided into four parts. The first part of 52 pages is devoted to the explanation and description of the art of distillation and of the utensils used, in parts two and three the preparation and action of the distilled waters are described, and in the fourth part the preparation of the *Aquæ vitæ*, of oils and balsams.

Distillation is explained in a manner similar to that of Brunschwig given 56 years before, but it is more explicit (fol. 45):

"Die rechte gründliche Distillation an ir selbs ist nichts anders, dann ein abzug der natürlichen feuchten von gewechs, oder andere irdischen materi, durch gewalt der hitz abgezoge oder abgetriebe. Solche herrliche kunst ist den alten Griechischen ärzten und Philosophen unbekant gewesen und ein neuer fundt und aufbringens der nachkommenden, zum theyl erdacht und nützlich erfunden von wegen der zartigkeit der menschen diser zeit, so allein, was in auch wohlschmecket, für nützlich achten, dann zu dem dass solche künstliche Abtractiones, oder gedestillierte was-ser, öl, aquæ vitæ, und andere dergleichen stück sehr nützlich und künstlich, also, dass sie ir gewaltige Wirkung, welehe sie vermögen in menschlichem körper zu erzeygen, ganz augenscheinlich darthun und wirken. . . .

Es haben aber die natürlichen Philosophi solche Kunst des Destillierens erstlich abgenommen in nachfolgung der natur, welche natur in der grössern welt durch kraft und macht der Sonnen und hitz die dämpff in der erden

¹⁾ The following bit of criticism by Ryff may here be quoted: *"Es wird die hochlöbliche Artzney nit aus Kräutterbüchern oder aus schlechtem teutschen schreiben gelemet, wie leyder jetzo solche kunst nit in geringen missbrauch kompt viles teutsches unformiges schreibens halber, welches auch von etlichen die grossen name in medicina haben wöllen geschicht. Aus solchem schreiben will dann jeder artzniren unn geschicht dardurch, dass der gemein man und etliche geachte leut iren leih anvertrauen einem Zanhrer, Juden, Moench und alten vetteln. Dann bei diesen gilt mehr das geschwetz und der rühm, dann die ware kunst. Wie da sagt das carmen:*

*Sæpe rudes tantum facit ostentatio doctos,
Sæpius hæc rudibus nomina magna dedit.*

Das ist:

*Kannst du dich dapffer geben aus,
Mit rühm und schwatz hoch prangen raus,
So wirst du haben rühm und gunst,
Ob du gleich seist ein esel sunst."*

verborgen, fürnemlich von wasser und feuchtigkeyt auffzeuchet, oder aufftreibet bis in die mitler region des luffts, von welcher sie zusammen getriben werden in einn nebel und wolken, so sich dann der selbig zerspreytet und schmelzet in Regen, Schnee oder Hagel, fallet er widerum herab zur erden. . . .

Solche natürliche abzuehung der feuchte von ein ding und gewechs haben unsere vortfahren abgenommen aus obgemelter wirkung. Haben also die materi, von welcher sie solche feuchte haben abziehen wollen, in ein grösser Geschire, so unden in die rinde weit mit einem Bauch zusammen gethon, welches Instrument sich in der proportion der Spheren, darinnen wasser und erdreich versammelt, vergleicht wirt. So nun solche feuchte von der nunderlegten hitz verdünnet und gesubtilirt, wird sie obersich getriben, wo sich solche aufsteigende vapores wider erküelten und von der kelte gedensiert, sich dann in wasser zerlassende oder zerschmelzend, welcher durch solchs obergeless bequemerlicher ausgeführt, gesammelt und zu mancherley nutzharkeyt behalten und gebraucht werde." (New gross Destillirbuch, fol. 175 189.)

In the last part of the book he also describes "the correct method of preparing by distillation, according to the rules of art, several precious oils". These are distilled, some of them with wine, from myrrh, liquid storax, sagapenum, opopanax, ammoniac, styrax calamita, sacocolla, benzoin, labdanum, galbanum, turpentine, mastic, sandarac, guaiac wood, rosemary, spike, anise, cloves, cinnamon, mace, saffron, and from various mixtures of spices (balsams).

Under spike and lavender oils (fol. 186) he mentions that these oils are commonly imported from France in small bottles and sold at a high price.¹⁾

How little Ryff knew about the nature of volatile oils and how primitive were his methods of preparation, becomes apparent from fol. 187 and 188 of his "Destillirbuch" where he describes "how from several strong and good spices precious oils can be distilled." To prepare specially good oils from cloves, nutmeg,

¹⁾ In the "Reformirte Apotheke" published by Gualtherus Ryff in 1563 the following interesting statement is found (fol. 191): "When lavender flowers are distilled, a very fragrant oil usually floats on the surface. In the French Provence, about Narbonne, where this plant grows abundantly, a specialty is made of the distillation of this oil. Oils are likewise distilled there from other useful and fragrant herbs, flowers, fruits and roots."

This statement is of historical interest since it is probably the earliest reference in German literature to the volatile oil industry which apparently existed in France as early as the 16. century.

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"Die rechte gründliche Distillation an ir selbs ist nichts anders, dann ein abzug der natürlichen feuchten von gewechs, oder andere irdischen materi, durch gewalt der hitz abgezoge oder abgetriebe. Solche herrliche kunst ist den alten Griechischen ärzten und Philosophen unbekant gewesen und ein neuer fundt und aufbringens der nachkommenden, zum theyl erdacht und nützlich erfunden von wegen der zartigkeit der menschen diser zeit, so allein, was in auch wohlschmecket, für nützlich achten, dann zu dem dass solche künstliche Abtractiones, oder gedestillierte was-ser, öl, aquæ vitæ, und andere dergleichen stück sehr nützlich und künstlich, also, dass sie ir gewaltige Wirkung, welehe sie vermögen in menschlichem körper zu erzeygen, ganz augenscheinlich darthun und wirken. . . .

Es haben aber die natürlichen Philosophi solche Kunst des Destillierens erstlich abgenommen in nachfolgung der natur, welche natur in der grössern welt durch kraft und macht der Sonnen und hitz die dämpff in der erden

¹⁾ The following bit of criticism by Ryff may here be quoted: *"Es wird die hochlöbliche Artzney nit aus Kräuttrbüchern oder aus schlechtem teutschen schreiben gelemet, wie leyder jetzo solche kunst nit in geringen missbrauch kompt viles teutsches unformiges schreibens halber, welches auch von etlichen die grossen name in medicina haben wöllen geschicht. Aus solchem schreiben will dann jeder artzniren unn geschicht dardurch, dass der gemein man und etliche geachte leut iren leih anvertrauen einem Zanhrer, Juden, Moench und alten vetteln. Dann bei diesen gilt mehr das geschwetz und der rühm, dann die ware kunst. Wie da sagt das carmen:*

*Sæpe rudes tantum facit ostentatio doctos,
Sæpius hæc rudibus nomina magna dedit.*

Das ist:

*Kannst du dich dappfer geben aus,
Mit rühm und schwatz hoch prangen raus,
So wirst du haben rühm und gunst,
Ob du gleich seist ein esel sunst."*

pointed out, the treatises mentioned above were not only re-printed but imitated in Germany as well as outside of Germany.

The professional scholars of this period who were most prominent because of their comprehensive knowledge and literary activity were Valerius Cordus and Conrad Gesner. Their works appeared about the middle of the sixteenth century and somewhat later. They were not only modeled after the earlier treatises but excelled them by a more thorough knowledge, by clearer exposition, and by greater wealth of material. Hence they were generally appreciated and recognized by municipal authorities.

Valerius Cordus (born 1515 in Simshausen, Upper Hessa; died 1544 in Rome), whose father was Professor of Medicine in Marburg, studied medicine at his home receiving the academic baccalaureate in 1531. In the same year he went to Wittenberg to attend the lectures by Melanchthon. Having soon obtained the *venia docendi*, he lectured on the *Materia medica* of Dioscorides.

These lectures of Cordus appears to have put down in writing. Five years after his death the German translation of these lectures was published in Frankfurt-on-the-Main by Ruellius. The commentaries on Dioscorides, also other scientific writings by Cordus were published in 1561 (possibly as early as 1557) by Conrad Gesner of Zuerich (born 1516, died 1565), who was a many sided scholar and a profuse medical writer. To the commentaries of Cordus were added not only additions by Gesner but an entire treatise by the latter.¹⁾ Only a single treatise

¹⁾ This folio bears the following title: *In hoc volumine continentur Valerii Cordi Summusii Annotationes in Pedaceii Dioscoridis Anazarbei de medica materia libros quinque longe aliae quam antea sunt hac sunt evulgatae.*

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De artificiosis extractionibus liber. Compositiones medicinales aliquot non vulgares. — Hic accedunt Stockhornii et Nessi in Bernatium Helvetiorum ditio montium, et nascentium in eis stirpium, descriptio Benedicti Aretii Græcæ et Hebræicæ linguarum in schola Bernensi professoris clarissimi. Item Conradi Gesneri De Hortis Germaniæ liber recens una cum descriptione Tulipæ Turcarum, Chamæcerasi montani, Chamæopiti, Chamæventii et Conizoidis. — Omnia summo studio atque industria doctissima atque excellentis viri Conr. Gesneri medici Tigurini collecta et præfationibus illustrata. — 1561 Argentorati excudebat Josias Ribelius.

appears to have been published by Cordus himself, viz. a botanical work, the *Historia plantarum*, a description of plants used in medicine. It is a folio of 224 pages with numerous illustrations and appeared 1540.

These "Annotationes" of Cordus are of special importance in the history of volatile oils, partly on account of the reputation of the author, partly because of his knowledge of the subject and also because they appeared in a century that was so productive of literature. Whereas Brunschwig's book reveals a retrogression in the technique of distillation as compared with the Arabian period, Ulstad, Ryff, Matthiolus, Lonicer and others advanced the art during the period of distilled waters and *aqua-vitæ* in several ways: they not only made known many of the older pieces of apparatus that had been forgotten, but they also improved them and invented new ones.

The ground thus prepared was further cultivated by Cordus and Gesner. Owing to the short life time of the former, it was the latter who continued their common labors and realized better results.

In the chapter *de destillatione oleorum* (fol. 226) of the *Liber de artificiosis extractionibus* of his *Annotationes*, Cordus discusses the nature of the plant extracts obtained by expression and distillation. Concerning the oily plant constituents, Cordus distinguishes between the viscid, fatty oils (*Oleum crassum, viscosum, terrestre*) obtained by expression, e. g. of seeds, and those of a spirituous nature (*ærea*) which can be separated from the "terrestrial" substances by distillation. As illustrations of the first class, he mentions a number of the common fatty oils, as illustrations of the second class the oils of carpobalsam,¹⁾ cardamom, cubeb, pepper, cloves, cinnamon, mace, nutmeg, lignaloes and those of some of the common umbelliferous fruits, such as anise, fennel, caraway, cumin, angelica, Ligustrum, Libanotus, Pastinaca, Apium, Petroselinum, Pimpinella and Anethum.

In his description of the properties of volatile oils, Cordus makes mention of the remarkable property of the oils of anise

¹⁾ Carpobalsamum is the name applied to the fruits of *Balaamea meccanensis*, Gleditsch (*Balsamodendron Opobalsamum*, Kunth), which were formerly used medicinally.

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"Ein kostlicher theurer Schatz des Euonymus Philiatrus, darinnen behalten sind vil heymlicher güter stuck der arzney, lüternemlich aber die art und eygenschaften der gebrannten wasseren und ölen, wie man dieselbigen bereiten sölle: desgleychen yeder wasseren und ölen art und eygenschaafft, nutz und brauch. Item alles mit schönen lieblichen ligürinen angezeigt unnd Item wie man mancherley weyn bereiten sölle, auch den abgestandenen durch hilff der gehramten wasseren, gewürtzen unnd anderley materi widerumh heiffen möge lür die augen gestellt, ganz lustig, nützlich, und güt allen Alchemisten, haushalten: inbesonders den Balhierern, Apothekern und allen hehlhaheren der Artzney. — Erstlich in Latin beschrieben durch Eunnymum Philiatruin, unnd newlich verteutscht durch Johannem Rndolphum Landenherger zu Zürich: vormals in Teutsche sprach niemals gesähen. Getruckt in Zürich bei Andrea und Jacoho den Gessneren gebrüder im jar als man zalt von Christi unseres Heylands gehurt 1555."¹⁾

Later there appeared a second part also written by Gesner, but the original Latin text of which was not published until after his death, which occurred in 1565, by Caspar Wolf. A German translation by Jacob Nucsehler was published in 1583, likewise in Zuerich, under the following title:

Ander Theil des Schatzes Euonymi von allerhand künstlichen und bewerten ölen, wasseren und heymlichen Artzneyen, sampt ihrer ordentlichen hereytung und dienstlichen Figuren. Erstlich zusammen getragen durch Herrn Doctor Cunnrat Gesner, Demnach von Caspar Wollen der Artzneyen Doctor. Zürich; in Latin beschrieben und in Truck gefertiget, jetzt aber newlich von Johann Jacoho Nüscheler Doctoren, in Tütsche Sprach vertolmetschet. 1583.

Compared with Brunschwig's treatise which had appeared 50 to 65 years earlier, Gesner's treatises reveal a decided advance in the technique of distillation, also in his knowledge of volatile oils. The first German edition of 1555 contains several chapters "on distilled oils" (pp. 212—249) and on "balsams" and other mixed oils²⁾ (pp. 249—273). The distillation of a

¹⁾ This famous book went through a considerable number of editions in the course of a century or more and was evidently very widely read. The English translation, by Morvynge, appeared in 1559 under the title: *New booke of distillation called the treasure of Euonymus*. London 1559, 1564 1565. A French translation appeared at Lyons in 1555.

The nom-de-plume chosen by Gesner was most likely derived from *evonymus* = Spindle tree (*prik-wood*) and *philatros*, *φίλος ἰατρός* = friend of science of medicine.

²⁾ Literally: "Balsamen und anderen kostlichen krelltigen und artig zusammen gesetzten Oelen."

number of oils, viz.: of the oils of lavender, rosemary, rue, cinnamon, cloves, nutmeg and others, is described, and the description accompanied with cuts of the apparatus to be used; also the distillation of juniper berries and juniper wood by *destillatio per ascensum* and *destillatio per descensum*. (pp. 217 and 247). Of the oils of gum resins, oleoresins and resins, those of ammoniac, benzoës, galbanum, labdanum, myrrh, opopanax, liquid storax and styrax calamita, mastic and turpentine are described. The oils from guaiac wood and sandal wood and from several other woods and barks are mentioned (pp. 244—247) and their distillation described.

The second part published in 1583, which may be regarded as a new edition brought up to date, contains much the same material and illustrations.

To what extent Gesner's conception of the nature of the products of distillation was influenced by tradition, becomes apparent from the preface of the first German edition in which he praises the art of distillation as a means to obtain from medicaments

"Die aller reuest, edelst, krefftigste und durchtrugest substanz, so die arzet nennen das fuenfft waesen (quinta essentia), von der inneren, groben, yrdischen, unnueten und mitaugliche substanz abgesonderet und ausgezogen werden."

And further on he says:

"Dennach so ludest du in diesem buche vergriffen die fuertraefflichen und tugendreichen stuck und arzuyn, so die kuenstler, arzet und Alchymisten als sundere geheimnuessen und secret der natur, mit grossem fleyss verborgen und verhalten habend: als da sind die wohlriechenden wasser, die oel die aus kreuteren, gewaechsen, bluemen, fruechten und wurzeln gezogen und separirt werden."

A better understanding of the volatile oils themselves is revealed in the following passage from the first volume (p. 103):

"Lass ordentlich destillieren in waermer aessen, von der absunderung und scheidung des oels vom erdreych, so wirst du saehen von den selbigen materi, so auf diese art destillirt wirdt, ein feyn lauter, schoen und klaer wasser und oel herabliessen, welches in im hatt de luftt oder des luftts eigenschafft, und das wasser, das ist die substanz unn das waesen, so das Element luftt und wasser in im hatt."

However, the confusion of ideas concerning distilled oils on the one hand and aromatized fatty oils on the other still manifests itself repeatedly in the writings of Gesner and Cordus.

Thus in the chapter on "distilled oils" three and even four methods for the preparation of one and the same oil are described. Among these are found not only the method of distillation proper, but that of infusion and digestion (circulation) with fatty oils, e. g. rose oil (pp. 224 and 236), lavender oil (p. 337), marjoram, myrrh and other oils (p. 332).

According to Gesner's directions a preliminary moistening of the material to be distilled with spirit of wine (*aqua vitæ*) is recommended. The oils are designated as a „feiste Feuchtig-keit" which is inherent in the herbs, flowers and roots. Flowers which have a delicate odor, such as roses, jasmine, etc., are packed in layers into the still, each layer being separated from the next by a similar layer of perfectly odorless flowers or leaves. The latter are to take up the aroma and to transfer it to the distillate.

In addition to many admirable directions, Gesner's writings contain descriptions of methods of distillation which reveal a complete absence of a clear distinction between aromatized fatty and distilled oils.

Thus among other descriptions, Euonymus Philiatrus gives the following directions for the preparation of distilled oils of several spices, viz. from cloves, nutmeg, mace, benzoës, storax, myrrh, safran etc.

"Die Specerei wird grob gepulvert, dann mit aqua vitæ durchleuchtet und in den gläserne retorte gethan, und bei gelinder Wärme destillirt. Wenn das öl anfahrt zu fließen, so nimm die materi der specereyen aus dem kolben und thus in ein säcklin, welches wohl verhunde syc mit einem faden, und trucks aus under einer prässen. Also dass du beide bläsch der prässen wohl heiss machest. Und also gehört es sich das ausgetruckt öl destilliren, rectificiren und circuliren, damit auff diese weis das rein lauter öl werde geschieden von der groben yrdischen materi. Demnach mag man wohl widerumb die häpfeln putrificiren und digeriren mit dem vorgemeltem aqua vitæ, so von anderem abgestünderet worden. Unn zum letzten widerumb destilliren."

Thus the distillation was interrupted at the beginning, the fatty oil aromatised with the volatile oil was expressed, and the volatile oil separated from the aromatised fatty oil by distillation.¹⁾

For the distillation of the ethereal oil of flowers Philiatrus gives the following directions:

¹⁾ *Ein köstlicher theurer Schatz etc.* Edition of 1553, fol. 215—217.

„Die Blumen der Spicken oder des Lavender solt du eine kurze Zeyt lang sonnen in einer grossen gläsernen retorte und darnach ein wasser in einem alembik darvonnen destilliren und abziehen. Dieses Wasser durch den ganzen Sommer gesetzt an ein warme statt an die Sonnen, so treybt es lür und lür öl über sich, welches öl du allwägen solt von dem wasser separiren und absündern mit einem fädertlich und dasselbe fleyssig behalten in einem gläsernen guttern¹⁾ wohl vermachet und verstopfet.“²⁾

As the last of the important practitioner-scientists and authors during the period in which the treatises on distillation dominated, the many sided Neapolitan noble man, Giovanni Battista della Porta (born 1537, died 1615) should be mentioned. Of his works,³⁾ published in twenty books, two, viz. his *liber de destillatione* and his *liber de vinis* are of special importance to the history of distillation. Of all his contemporaries, all of whom, it is true, preceded him, he had the clearest conceptions of distillation and of the products of distillation. Both of the two books, which appeared about 1563 distinguish themselves from their precursors by a more comprehensive knowledge not only of the subject matter and literature, but also by means of originality in research and mode of presentation.

Porta makes a clear cut distinction between fatty expressed and distilled oils, describes their method of preparation, also the distillation of aromatic waters and the separation of the volatile oils from the water and the apparatus used for this purpose. However, even with this clear thinking and enlightened practitioner the term distillation conveys the traditional concept of various methods of separation and extraction of parts of plants. In like manner Porta adheres to the general use of the designation oil for certain hygroscopic preparations, e. g. *oleum ex salibus*, *oleum ex tartaro*, *oleum ex soda*, etc.

To what extent Porta's views concerning the nature of the distillation process and the changes produced by heat in general coincide with those of contemporaries, becomes apparent from

¹⁾ Flask.

²⁾ *Ein köstlicher theurer Schatz* etc. Edition of 1555, fol. 222.

³⁾ Jo. Baptistæ Portæ, Neapolitani, *Magiæ naturalis libri viginti, in quibus scientiarum naturalium divitiæ et deliciæ demonstrantur. Iam de novo, ab omnibus mendis repurgati, in lucem prodierunt.* Romæ 1563 — Antwerp. 1564 — Hanovæ 1619.

the preface (p. 367) to *De destillatione*, which constitutes book ten of his *Magiæ naturalis libri*.¹⁾

These sixteenth century treatises on herbs and their distillation, as well as a number of less important ones, were the principal handbooks for the preparation of medicaments, especially of distilled waters, oils, and vinous distillates. At first they supplemented the older antidotaries, later they replaced them. The gradual change from these treatises on distillation to the so-called dispensatories is marked by the appearance of several works classed with the latter. Those of Ortolff Meydenberger,²⁾ and the later ones of Otto Brunfels³⁾ (born 1488, died 1534), Leonhard Fuchs⁴⁾ (born 1501, died 1566) and of W. H. Ryff⁵⁾ (first half of sixteenth century) may here be mentioned.

With the appearance of Paracelsus (1493—1541) and the spread of his iatrochemical ideas in medicine, vegetable remedies lost their former importance, their place being taken more or less by chemical products. Thus the distilled waters had to surrender their supremacy and with it the herbals and treatises on

¹⁾ "Iam ad artes deveniunt est, et a distillatione duximus sumendum initium neotericorum inventum, res infra ultra mortalem sortem laudanda, non quæ a sciolis et vulgaribus usurpari solet, nam verum esse corrumpunt, destruuntque sed ad causam gnaris pertractata. Docet enim hæc ars admirabilis, ut gravia corpora fiant spiritus et sublimet et spiritus crascescant ac corpora evadant. Remittunt vires, quæ mole obrutæ cunctatæ, suis veluti in locis delitescunt puriores, tenuiores et absque ulla impuriore materie accessione e plantis, metallicis, lapidibus et gemmis elicere, easque veluti non sua forte contentas, nobiliores in sublime educere, ac veluti in celum sustollere, poterimus chymisticis organis plantarum virtutes investigare et melius quam veteres gustu. Quid igitur majus poterit excogitari. Natura est res producere, ac viribus ditare, artis est productas nobilitare, ac multiplicibus viribus ditare. Accedat lector quædam, a natura secretorum perscrutator, nam distillationes haudquaquam inglorius tractabit. Primo aquas et olea extrahemus, mox esse tincturas, elixires, sales et ejusmodi similia. Mistum quodammodo in elementa dissolvere, ac singula puriora reddere, varias et adversantes, suas facultates separare et elicere, ut ex voto uti possimus, aliaque, quæ scisse et novisse non pœnitebit."

²⁾ Ortolff von Bayrland. *Arzueibuch. Hie lahet an eyn bûchelîn vum manigerley Artzeney.* Mainz 1485.

³⁾ *Spiegel der Arznei.* Strassburg 1532. — *Reformation der Apotheken.* Strassburg 1536.

⁴⁾ *De componendorum miscendorumque medicamentorum ratione.* 1549.

⁵⁾ *Reformirte deutsche Apothek.* Frankfurt a. M. 1563.

distillation lost in importance. The volatile oils, however, gradually taking the place of the distilled waters, gained in importance. This change was contemporaneous with the transition from the *Destillirbücher* to the dispensaries. Although this change was brought about gradually, it is usually identified historically with the appearance of the *Dispensatorium Noricum* of Valerius Cordus in the year 1546.

While in Wittenberg, Cordus (born 1515, died 1544) was in the habit of visiting with his uncle, the apothecary Ralla, who from 1532 to 1560 was proprietor of the *Salomo-Apotheke* in Leipzig. Here he seems to have taken an active interest in the art of distillation and in making chemico-pharmaceutical preparations. At Ralla's instigation and with his assistance, Cordus collected tried formulas for the preparation of distilled waters and other pharmaceutical preparations. These were published by Ralla.

This compilation, and still more his lectures on the *materia medica* of Dioscorides as well as his *Historia Plantarum* published in 1540, had established the fame of the young scholar. On one of his botanical excursions, Cordus appears to have stopped at Nürnberg where he received due attention in medical circles. In 1542 the council of that city charged him with the preparation of a dispensatory for the guidance of physicians and apothecaries of that municipality. This task Cordus accomplished with the aid of his uncle Ralla and of Caspar Pfreund, a friend and able apothecary at Torgau. The book was favorably received by the council of Nürnberg and was published in 1546, two years after the death of its author.¹⁾ Several editions appeared in rapid succession without date of publication, the third Nürnberg edition bearing the date 1548. As an authoritative treatise, the book seems to have found general recognition. It was frequently re-

¹⁾ *Pharmacorum omnium, quæ quidem in usu sunt, conficiendorum ratio. Vulgo vocant Dispensatorium pharmacopolarum. Ex omni genere honorum authorum, cum veterum tum recentium collectum, et scholiis utilissimis illustratum. in quibus obiter, plurium simplicium, hactenus non cognitorum vera noticia traditur. Authore Valerio Cordo. Item de collectione repositione et duratione simplicium. De adulterationibus quorundam simplicium. Simplicium aliquo absolute scripto, quid sit accipiendum, ἡντιπαλλόμενα, id est, Succedanea, sive Quid, pro Quo. Qualem virum Pharmacopolam esse conveniat. Cum indice copiosa. Norimbergæ, apud Joh. Petrelium.*



Fig. 3.

printed, both in its original form and with the additions made by Conrad Gesner.

The long title of this work was abbreviated to *Dispensatorium Noricum* and it is commonly regarded as the first German pharmacopœia, though this is not quite true.¹⁾ It was recognized as standard up to the close of the seventeenth century, although twenty years later it had to share honors with the Augsburg Pharmacopœia of Adolph Oeco.²⁾

Notwithstanding the want of a clear understanding of the nature of the distilled oils during the whole of the sixteenth and part of the seventeenth centuries, their preparation was fostered and their use in medicine, the arts and in the household increased. Among the medical experimenters and writers of this period, [Johann Winther,³⁾ who was born 1487 in Andernach and who died 1574 as professor of medicine in Strassburg, seems to have distilled a large number of the more common volatile oils with great care.

Moreover, the distillation of aromatic waters and volatile oils was now being conducted principally in the pharmaceutical laboratories where both the process and the utensils were variously improved in the course of time.⁴⁾

In addition to the Nürnberg and Augsburg pharmacopœias

¹⁾ See p. 58.

²⁾ *Pharmacopœia seu Medicamentarium pro Republica Augustana*. Author Adolphus Oeco. *Augusta Vindelicorum* 1564.

Of this pharmacopœia there also appeared numerous reprints and editions as late as 1734. The titles of many of these are often modified by such terms as *reformata, renovata et aucta*.

The great demand for both of these pharmacopœias, which lasted a century and a half, is largely due to two reasons. First, these new pharmacopœias satisfied the practical demand better than did the older *Antidotaria* and the more recent treatises on distillation. Secondly, it was due to the rapidly increasing number of apothecary shops that were established during the 16. and 17. centuries.

³⁾ Guintheri Andernaci *Liber de veteri et nova medicina tum cognoscenda tum facienda*. Basilæ 1571.

⁴⁾ On p. 59 will be found the title page of such a pharmacopœia of the *Res publica Gorlicensis* of 1629. It is characterized not only by the predominance of illustrations pertaining to the art of distillation, but also by the expression given to the sense of order prevailing in all laboratories of apothecary shops.

and similar authoritative works, the municipal price ordinances, which since the sixteenth century were issued in various cities to regulate the sale of drugs and spices, are reliable sources of information concerning the introduction of distilled oils into medicine and the arts. As documents they are of similar importance to the price lists of modern wholesale merchants and manufacturers.

The following list has been prepared with the aid of the previously discussed historical documents.¹⁾ It should, however, be definitely understood that the dates given are not necessarily those of the first introduction or use, but those of their legal recognition as articles of commerce.

DISTILLED OILS KNOWN AND IN USE:²⁾

Up to the beginning of the sixteenth century:

The oils of benzoin, calamus, cedarwood, costus root, mastix, rose, rosemary, sage, spike, turpentine, juniperwood, frankincense, cinnamon.

TO THESE WERE ADDED:

From 1500 to 1540:

The oils of lignaloes, angelica, anise, cardamom, carphalsam,³⁾ cuheh, wild caraway, fennel, caraway, ilhanotis, lovage, mace, nutmeg,

¹⁾ In addition to the *Destillirbücher* previously mentioned, the following pharmacopœial works have been used in the compilation of this list: Of the *Dispensatorium Noricum* the editions of 1546, 1552, 1559, 1563, 1580, 1589, 1592 and 1612; of the *Pharmacopœa Augustana* the editions of 1580, 1597 and 1640; and the *Dispensatorium Brandenburgicum* of 1698.

Of the large number of municipal price ordinances the following were consulted: Frankfurt-on-the-Main, for 1582, 1587, 1668, 1710; Nürnberg, for 1552, 1613, 1624, 1644, 1652; Worms, 1582; Strassburg, 1586; Wittenberg, 1599, 1632; Halberstadt, 1607, 1697; Halle 1643, 1700; Ulm, 1649; Bremen, 1644, 1664; Dresden, 1652; Leipzig, 1669, 1689, 1694; Berlin, 1574.

²⁾ Bitter almond oil and several other poisonous oils, such as cherry laurel oil were excluded from general commerce on account of their poisonous properties. Hence they do not appear in the price ordinances. Inasmuch as they were not used medicinally when they first became known, they do not appear in the pharmacopœias. Both of the above mentioned oils were known before the middle of the sixteenth century, bitter almond oil even during the middle ages. Oils of animal origin are not mentioned in the above list.

³⁾ *Carpobalsamum* is the name applied in the fruits of *Balsamea meccanensis*, Gleditsch (*Balsamodendron Opobalsamum*, Kunth) which were formerly used for medicinal purposes.

Pastinaca sativa, L., pimpinella, pepper (from *Piper nigrum*), celery, sandal wood, juniper berries, juniper tar (*Oleum cadinum*), mastix.

From 1540 to 1589:

The oils of elecampane, ammoniac, horehound, anise, asaetida, basilicum, bdellium, mountain melissa (*Calamintha montana*), mountain thyme (*Thymus acinos*), amber, citrius, coriander, "costiver", dill, organum, sweet marjoram, elemi, galbanum, galangal, guaiac, chamomile, Roman chamomile, spearmint, labdanum, lavender, lemon, spoonwort, laurel, *marum verum*, marjoram, balm, mints, carrot seeds, feverfew, cumin, myrrh, cloves, opopanax, parsley, pepper (from *Piper longum*), summer savory (*Satureja hortensis*), European penny-royal, orange peel, tansy, wild thyme, rue, rhodium, saffron, sagapenum, sandarac, sassafras, false cumin, storax, tacamahac, thyme, iris, wormwood, hyssop, zedoary (root).

From 1589 to 1607:

The oils of *Cheraphyllum bulbosum*, peppermint, savin, white mustard, seseli, zedoary (flowers).

From 1607 to 1652:

The oils of ginger, arbor vitae, costmary (*Tanacetum Balsamita*).

From 1652 to 1672:

The oil of cow-parsnip (*Heracleum sphondylium*), cascarilla, cypress, *Anthriscus cerefolium*, *Eupatorium canadense*, black mustard.

From 1672 to 1708:

The oils of valerian, bergamot, mugwort, box-tree, masterwort, neroli, *Oleum templum* (from *Pinus Pumilio*).

From 1708 to 1730:

Bitter almond oil and oil of capeput.

At the beginning of the seventeenth century a change took place in the tendencies underlying alchemistic activities. These were accompanied by the transition of the practice of the art of distillation to the laboratories of apothecary shops. They were due also, in part, to the revival of the desire for the transmutation of the metals and for the discovery of the *lapis philosophorum* that had been sought for many centuries. The place of distilling apparatus was resumed by furnaces and subliming apparatus. Having failed to find the panacea for all ills and the fount of youth in organized nature, attention was again directed to mineral and metallic substances.

Chemical science was continuously driven to false conclusions, not only by its experiments to convert base metals into gold, but also by its search for a *quinta essentia* by means of a separation of the "subtle and spirituous" from the "coarse and earthy" by means of distillation and sublimation. False doctrines frequently guided both the plan and execution of alchemistic research, and thus influenced the object of the experiment as well as the interpretation of the phenomena observed. Consequently, the results were correspondingly uncertain and often a matter of accident. Thus chemical knowledge proved a false structure without internal coherence. Considerable as was the sum total of empirical progress made during the sixteenth and seventeenth centuries, it served merely the purpose of supplying building material for a later period. Included in this progress was the discovery of numerous useful chemical preparations and volatile oils. In like manner as the *lapis philosophorum*, the highest and final power of (inanimate) nature was being sought in the former, so the *quinta essentia*, the true panacea for the restoration of health and the prolongation of life, was sought in the latter. Thus Philipp Ulstad and other enlightened investigators of the sixteenth century thought they had discovered this *quinta essentia* in the spirit of wine. Each success, true or only apparent, stimulated the disciples of spagyric and alchemistic art to renewed activity and strengthened their belief in the imaginary powers of the coveted products. To this class belonged the majority of medical and pharmaceutical laboratory experimenters.

Although the diligent practice of the art of distillation brought about considerable progress in the technique, the conception of the nature of the products remained under the bann of the traditional theosophic doctrines. This was also the time when the thirty years war produced such disastrous effects upon the cultural and spiritual life of Germany. This religious war, in which Germany fared worse than any other country, destroyed wealth and well being, and for nearly a century crippled the scientific and commercial life of the nation. Traditional knowledge and practice in the arts and crafts was largely lost. Superstition and the spagyric art were revived and abstract alchemy flourished once more in Christian Europe as it had done in the Arabic world.

Whereas during the period described above, aromatic waters were used for medicinal purposes in Europe and more particularly in Germany, in Asia fragrant drugs of vegetable and animal origin, also the aromatic waters and aromatized fatty oils prepared from them were used extensively in religious ceremonies and in perfumery. Interesting accounts concerning these perfumes are found in the "Ain-i-Akbari", the annals of the emperor Akbar (1542—1605) written in the Persian language by his historian Abul Fazl toward the close of the 16. century.¹⁾

Linalocs, which formerly played an important role, was comminuted and buried, thus causing the inferior portion to decay whereas the portion richer in resin, the pure linaloes, remained. It was used for a variety of purposes: as a medicine, in perfumery and fumigation, as insecticide, etc. The oil of linalocs, the Chuwah, is distilled by covering the comminuted wood with water in an earthenware flask, the neck of which is connected with a dish containing water. With the aid of a moderate fire the oil is driven over into the receiver. In order to remove the smoky odor, the oil is washed with water, the oftener the better. Concerning the history of rose oil, which was introduced into India by way of Persia, the following statement is made. In the imperial garden the bride of the emperor Jehangir observed a film on the surface of the canals which were supplied with rose water. This film she had collected and the oil thus obtained she named after her husband *Atr-i-Jehangiri*. Other fragrant waters, e. g. those prepared from orange and jasmine flowers, were known by the collective name of *Araq*. The fragrant grasses *Andropogon Schoenanthus*, *A. muricatus* and *A. laniger* are met with under the names *Rus* and *Abir Izkhir*. Of resins storax, benzoes, frankincense and labdanum are mentioned as being known. The last mentioned is described correctly as a substance obtained from *Cistus*, "a Cyprian and Chiotie tree". It is also obtained from the beards of goats who have eaten *Cistus* leaves. This second quality is regarded as the better.

Of camphor it is said that it was first found in a country not far from Ceylon. A substitute perfumed with camphor was

¹⁾ David Hooper, The perfumes of the Moguls. Calcutta Review, October 1904. — Report of Schimmel & Co., October 1905, 83.

also known. By means of it "people without a conscience tried to enrich themselves at the expense of others." Borneo camphor was also highly prized.

Of minor importance are perfumes obtained outside of India, such as orris root, wormseed and patchouli leaves.

Of animal perfumes ambra, civet and musk are mentioned.

During the period under consideration all endeavors were directed toward the artificial preparation of gold. As a result there were more adepts during the 17. century than during the two previous centuries. Many courts, suffering from want of money, became the fruitful fields cultivated by the adepts of the spagyric art. Of these, only very few attained practical results of any kind, as did, *e. g.*, the alchemist Böttger (born 1685, died 1719) who discovered the art of making porcelain. Chemically this poverty stricken century accomplished but little. Princes, scholars, physicians, indeed members of all classes of educated society were open or secret adherents and believers in the transmutation of the metals.

These endeavors which forced into the background all true chemical research, appear likewise to have caused a prolonged stagnation in the art of distillation. During the 17. century it was practiced only by a few experimenters far away from the turmoil of war that raged on German soil. Among these should be mentioned in particular Joh. Baptista van Helmont in Brussels (born 1577, died 1644), Johann Rudolf Glauber in Amsterdam (born 1604, died 1668), Nicolas Lemery in Paris (born 1645, died 1715), and Wilhelm Homberg in Paris (born 1652, died 1715).

During this period the practice was introduced of adding salts, such as common salt, potash, alun, and tartar to the water in the still. The object sought was to increase the gravity of the water so that the parts of plants might not so readily adhere to the bottom of the still and become empyreumatic. Presumably it was also observed in certain instances that an increased yield of oil resulted. The addition of hydrochloric acid, however, as recommended by Glauher must be characterized as going astray.

Even with these assumed improvements, the art of distillation at the close of the 17. century still rested on the basis of

empirical experimentation. Neither was it advanced by the phlogistic theory, proposed toward the end of the century by J. J. Becher (born 1635, died 1681) and more firmly established by G. E. Stahl (born 1660, died 1734), which theory permeated all chemical speculation for more than a century. Even if this theory, that characterized the last transition period of theoretical chemistry, was ingenious and productive, and prepared the way for the chemical reformation that occurred toward the close of the 18. century, it failed utterly to throw light on the composition of the volatile oils. Moreover the elemental components of air and the constituents of water, also the elements of which minerals and rocks are composed were known only in part up to the middle of the 18. century.

Renewed progress, however, in the manufacture and use of volatile oils is to be recorded during the eighteenth century. The technique of distillation was improved in the laboratories of the apothecary shops where the oils were largely distilled and a better product was prepared. The distilled oils were not only prepared on a larger scale and of better quality, but they found extended application not only in medicine, but also in the arts and in the household. The number of oils mentioned in municipal price ordinances and other literature up to 1500 had been only thirteen; in 1540 the number had increased to thirty-four and in 1589 to one hundred and eight oils. The *Dispensatorium Noricum* of Cordus mentions only three oils in 1543; the edition of 1552 mentions five; that of 1563 six; and that of 1589 fifty-six distilled oils. In 1708 one hundred and twenty oils are mentioned in the price ordinances of that time.

The distillation of pure volatile oils and the skill to mix them so as to produce agreeably fragrant mixtures, not only stimulated the improvement of methods of preparation, but also their extended use. With the distillation of the oils of lavender and rosemary, a volatile oil industry, as has already been indicated,¹⁾ seems to have developed from small beginnings in southern France during the fifteenth and sixteenth centuries. In like manner, the perfume industry seems to have had its origin. The preparation of "Hungarian water" in the sixteenth century by making

¹⁾ See p. 48.

an alcoholic distillate from fresh rosemary has already been referred to.¹⁾ During the seventeenth century, a *Karmeliter Geist*, an alcoholic distillate from balm and lavender,²⁾ was introduced. In 1725 Johann Maria Farina of Cologne introduced his famous *Eau de Cologne*. The successful mixture of several odors and the prime quality of the oils used proved an important stimulus to the manufacture of these oils.³⁾ From these small beginnings the perfume industry gradually developed into the important position it has held since the middle of the past century.

With the increased importance of the volatile oils, more attention was bestowed upon their nature and composition. Boerhaave (born 1668, died 1738), who at the beginning of the eighteenth century was professor of medicine, botany and chemistry at the University of Leyden, in his treatise on chemistry⁴⁾ states that volatile oils consist of two elements: the one cruder and resinous, insoluble in water (*mater*); the other more subtle, ethereal, which can scarcely be weighed and which by itself is possibly gaseous (*spiritus rector*). The first part he considered to be common to all oils and a unit by itself. The characteristic odor and taste, however, of the various oils were due to the *spiritus rector* which was peculiar to each oil. It was water soluble and therefore gave to the distilled waters their odor, taste and medicinal virtue. The changes produced in volatile oils upon exposure to air and light were attributed, in harmony with this theory, to the escape of the *spiritus rector*.⁵⁾

This conception was perfectly in harmony with the belief, current during the middle ages and up to the 17. century, in

¹⁾ See p. 30.

²⁾ See the history of the oils of lavender and spike.

³⁾ See the history of oil of balm.

⁴⁾ *Elementa chemiæ, quæ anniversario labore docuit in publicis privatisque scholis*, Hermannus Boerhaave. *Tomus primus, qui continet historiam et artis theoriam. Tomus secundus, qui continet operationes chemicas*. Lugduni Batavorum 1732 — Londini 1732, 1735 — Parisii 1732, 1733, 1753 — Lipsiæ 1732 — Basilæ 1745 — Veneti 1745, 1759.

⁵⁾ *In hoc autem oleo essentiali rursus subtilissimus, volatilis, paucus, acerrimus, vix ponderandus, spiritus iterum complectitur illud omne, quod huic toti oleo dabat hanc vim; eoque ablato nihil in oleo. . . . Inquisivi in pondus spirituum, invenire non potui est.* (Boerhaave's *Elementa chemiæ*, Tom. 2, p. 124—131.)

the subtle properties and medicinal virtues of aromatic plant substances and their aqueous distillates. With the assumption of the water solubility of the *spiritus rector* the distilled waters were naturally regarded as being charged in the highest degree with the medicinal properties of the crude drugs. Boerhaave's dualistic theory concerning the composition of the volatile oils was therefore received as the most rational explanation of the firmly established belief in the efficacy of distilled waters, and was also accepted as a further argument for their retention in medicine. Even after the antiphlogistic nomenclature came into vogue after 1787, the *spiritus rector* was not discarded, being rebaptized as *arôme*.

The first chemists who discarded the dualistic theory of the volatile oils in their writings, and claimed that odor and taste are due to the oil as such, are F. A. C. Gren,¹⁾ Professor of Medicine in Halle, and the French chemist Ant. François de Fourcroy²⁾ of Paris. The former exposed the untenability of Boerhaave's theory in 1796, the latter in 1798. Indeed Fr. Hoffmann (born 1660, died 1743), a contemporary of Boerhaave and professor at Halle, had not accepted the latter's theory without reserve. A many-sided investigator and writer, he had prepared and studied the volatile oils with great care.³⁾ Yet he had no clearer conception concerning the nature and composition of the oils than his contemporaries. He distinguished between oils obtained by expression, by *destillatio per ascensum* and *per descensum*.⁴⁾ He regarded sulphur as a fundamental principle of all oils, the bituminous and empyreumatic oils containing a

¹⁾ Grens *Grundriss der Chemie nach den neuesten Entdeckungen entworfen und zum Gebrauche akademischer Vorlesungen eingerichtet*. Halle 1796. Vol. 2, p. 217.

²⁾ *Annal. de Chim.* 25 (1798), 232 and Fourcroy, *Système des connaissances chimiques*. Paris 1801.

³⁾ *Frederici Hoffmannii Opera omnia physico-medica. Denno revisa correcta et aucta. In sex tomos distributa*. Geneva: 1740–1761 Veneti 1745, 17 Volumina — Neapel 1753, 25 Volumina.

⁴⁾ The *destillatio per ascensum* corresponds to the method now generally used, allowing the vapors to pass upwards in the still and removing them from above. In the *destillatio per descensum* the vapors were forced downward through the material and collected in a receptacle underneath the still. An incomplete extraction was thus effected. (Comp. chapter IV.)

relatively large amount of sulphur.¹⁾ He also believed that the color and odor of oils was influenced by their larger or lesser sulphur content.

It should be of interest to note that camphor which had been regarded as a volatile organic salt, was pronounced by Hoffmann to be a congealed volatile oil.²⁾ He also made the observation that most of the commercial oils of his time were adulterated with turpentine oil, *oleum vini*, alcohol and fatty oils.³⁾ Further he determined the yield⁴⁾ and specific gravity⁵⁾ of many oils. At the beginning of the 18. century, distillation was regarded as a well known and universally practiced method of laboratory technique. Hence the special interest of that period was directed mainly toward the determination of the yield of oils and the study of their properties. This interest was, no doubt, stimulated by Glauber's suggestion to rectify by distillation with dilute muriatic acid oils that had become colored by age.

Glauber's views⁶⁾ and those of his contemporaries were opposed by Hoffmann. He declared the employment of *spiritus salis*,⁷⁾ dilute sulphuric acid,⁸⁾ potash, tartar and alum⁹⁾ in the distillation of volatile oils as useless, but consented to the use of common salt. He argued that the addition of salt facilitated the separation of the oil particles and prevented decay; that

¹⁾ Frederici Hoffmannii *Opera omnia physico-medica. Denuo revisa correcte et aucta. In sex tomos distributa.* Genevæ 1740- 1761 - Vcneti 1745. Tom. 4, Liber 1, p. 449-451.

²⁾ *Ibidem.* Liber 72. *Observatio* 13, p. 44-50.

³⁾ *Ibidem.* Liber 67. *Observatio* 2, p. 9-11.

⁴⁾ *Ibidem.* Liber 65. *Observatio* 1, p. 1-9. "*De oleis destillatis inque eorum destillatione observanda.*"

⁵⁾ *Ibidem.* Liber 72. *Observatio* 8, p. 27-30. "*Gravitas specific oleorum.*"

⁶⁾ Johanni Rudolphi Glauberii *Furni novi philosophici.* Lugduni Batavorum 1648 Amstelodami 1648 Prag 1700. Pars 1, p. 35, 36 et 41, et pars 3, p. 30.

⁷⁾ *Ibidem.* Pars 1, p. 36. This was crude hydrochloric acid prepared by the distillation of common salt and alum or sulphuric acid.

⁸⁾ Crell's Chem. Journ. 3 (1780), 30. — Platt's *System der Materia medica.* 1815. Vol. 4, p. 50.

⁹⁾ Glauberii *Furni novi philosophici.* Lugduni Batavorum 1648 — Prag 1700. Pars 1, p. 38 et pars 3, p. 31.

it made the water "heavier" and thus prevented the settling and burning of the plant material; that it also purified the distillate.¹⁾

In some instances recourse was again taken to the process of fermentation before distillation which was in vogue during the fifteenth and sixteenth centuries. This was done e. g. with juniper berries, wormwood, sage and other herbs, honey and yeast²⁾ occasionally being added. The old practice of previously moistening the plant material with alcohol³⁾ was also resorted to. In this manner a larger yield of oil was obtained but it would seem that the dilution of the oil with alcohol was not recognized.

Downward distillation (*destillatio per descensum*) was applied by Hoffmann⁴⁾ in the preparation of oils with high specific gravity such as the oils of cinnamon and cloves. This method was evidently regarded as being better because the dark colored oils thus obtained were supposed to contain more sulphur.

With the increased use of volatile oils during the first half of the eighteenth century it became more and more desirable not only to prepare oils of good quality but to obtain the largest possible yield as well. As guides there appeared new treatises on distillation⁵⁾ which had little more than the title in common with the older *Destillirbücher*. They treated not only of distilled

¹⁾ Fr. Hoffmannii *Opera omnia physico-medica. Supplementum secundum*. Geneva 1760. Pars 1, p. 730.

²⁾ *Berlinisches Jahrbuch für Pharmacie* 1804, 380.

³⁾ Demachy, *Laborant in Großen, oder die Kunst die chemischen Produkte fabrikmäßig zu verfertigen*. Aus dem Französischen übersetzt, mit Zusätzen versehen von Samuel Hahnemann, der Arzneikunde Doctor und Physikus des Amtes Gommern. Leipzig 1784, p. 238.

⁴⁾ Fr. Hoffmannii *Opera omnia physico-medica*. Tom. 4. *Observationum selectiorum libri*. 1717. Liber 1, p. 449-451. — *Supplementum secundum*. 1760. Pars 1, p. 730.

⁵⁾ Of these the following are the more important:

Die zum allgemeinen Gebrauch wohl eingerichtete Destillirkunst. Auch die Bereitung verschiedener destillierter Wässer und Öle. Von C. H. Burghart. Breslau 1736. *Neue Auflage mit vielen Zusätzen* von J. Christian Wiegleb. 1754.

Das Brennen der Wasser, Öle und Geister. Wohleingerichtete Destillirkunst und neue Zusätze. Von G. H. Burghart. Breslau 1748.

waters, but also of volatile oils and spirit of wine. Coupled with the scientific problem of the distillation of the volatile oils was the commercial problem of the largest possible yield.

Following the lead of Winther,¹⁾ Boerhaave and Hoffmann, a number of investigators of the eighteenth century ascertained the yield of oil obtainable from the more common aromatic plant products. Of these the following deserve special mention: Joh. Fr. Cartheuser²⁾ (born 1704, died 1769), Professor of Medicine, Botany and Chemistry at the University of Frankfurt-on-the-Oder; Caspar Neumann³⁾ (born 1683, died 1737), a Berlin apothecary; Claude Joseph Geoffroy (born 1685, died 1752), a Parisian apothecary; and Guillaume François Rouelle⁴⁾ (born 1703, died 1770).

Their experiments were conducted on a small scale and with simple apparatus. Their results, however, published in their

Traité raisonné de la distillation, ou la distillation réduite en principes avec un traité des odeurs. Par Dejean. Paris 1753. — Deutsche Ausgabe, Altenburg 1754.

Traité des odeurs, Suite du traité de la distillation. Par Dejean. Paris 1764.

¹⁾ See p. 60.

²⁾ Cartheuser's researches on the volatile oils are contained in the following of his treatises:

Fundamenta materiæ medicæ. Francofurt. ad Viadr. 1738 and edition of Paris 1752.

Elementa Chymiae dogmatico-experimentalis, una cum synopsi Materiæ medicæ selectionis. Hallæ 1736. *Editio secunda priore longe emendatior.*

Dissertatio chymico-physica de generis quibusdam plantarum principiis hactenus neglectis. Francof. ad Viadr. 1754. *Editio secunda* 1764.

Dissertatio physico-chemica medica de quibusdam Materiæ medicæ subjectis exarat. ac publice habet nunc iter. resus. Francof. ad Viadr. 1774.

Dissertationes nonnullæ selectiores physico-chemicæ ac medicæ, varii argumenti post novam lustrationem ad prelium revocat. Francof. ad Viadr. 1778.

Pharmacologia theoretico-practica prælectionibus academicis accommodata. Berolini 1745.

³⁾ Caspar Neumann's researches on volatile oils can be found in the second volume of his *Chymia medica dogmatico-experimentalis, oder Gründliche mit Experimenten bewiesene Medicinische Chemie.* Published by Christ. Heinr. Kessel. 4 vols. Züllichau 1749—1755.

⁴⁾ Geoffroy's and Rouelle's work on volatile oils was published in the *Mémoires de l'académie royale des sciences de Paris* for the years 1730 to 1760.

works and in journals,¹⁾ were regarded as standard and were quite generally introduced into the literature on the subject. Through the dispensatory of the English physician and chemist, William Lewis,²⁾ the results of the above mentioned and of other continental investigators found their way into English literature.

Aside from the publications already mentioned, the interest shown in the study of volatile oils toward the close of the seventeenth and during the course of the eighteenth century is possibly best shown by the number of dissertations on the subject which were written at German universities under the stimulus of a number of university teachers.³⁾

¹⁾ In 1789, Remler of Erfurt collected and tabulated the observations relative to the yield and properties of volatile oils published up to that year.

A similar tabular compilation taking into consideration also the origin of the oils was published in the *Journal de pharmacie* for August 1834 by Raybaud of Paris in connection with the industrial exposition of the previous year. A German translation appeared in Buchner's *Repert. der Pharm.* for 1835, vol. 51, p. 54. Two further treatises on this subject appeared by G. H. Zeller in 1850 and 1855 respectively in the *Lehrbuch für praktische Pharmacie und verwandte Fächer*. The former appeared also as a separate under the title of *Studien über ätherische Oele*, Landau, 1850; the latter under the title *Ausbeute und Darstellung der ätherischen Oele*, Stuttgart, 1855.

²⁾ The new Dispensatory: Containing the theory and practice of pharmacy, a description of medicinal simples, according to their virtues and medicinal qualities, the description, use and dose of each article etc. Intended as a correction and improvement of Quincy. London 1753.

³⁾ The more important ones are herewith enumerated:

- 1670. *De oleorum destillationum natura et usu in genere. Dissertatio ab* David Kellner. Helmstadii.
- 1696. *De oleis destillatis. Dissertatio ab* Henrico Rosenberg. Jenæ.
- 1744. *De oleis destillatis empyreumaticis. Dissertatio ab* Christian Lindner. Francfurti ad Viadrum.
- 1744. *De sale volatili oleoso solido in oleis æthereis nonnunquam reperto. Dissertatio ab* Fr. Günther. Francfurti ad Viadrum.
- 1745. *De oleis vegetabilium essentialibus. Dissertatio ab* A. Fr. Walther. Lipsiæ.
- 1746. *De spiritu rectore in regno animali, vegetabili et fossili, atmosphærico. Dissertatio ab* Gottfried de Khora. Leydæ.
- 1747. *De oleorum destillatorum usu multiplice principue in castris. Dissertatio ab* Joh. Paul Ziegler. Altorfii.
- 1748. *Dissertatio chemica inauguralis sistens Dosimasiam concretionum in nonnullis oleis æthereis observatum ab* F. Hagen. Regiomontanae.

The investigations reported in these dissertations, however, rest on false premises and, therefore, produced no valuable results. Research based on the phlogistic theory and the doctrines of Boerhaave and Hoffmann concerning the constitution of volatile oils, could hardly be expected to yield results of any importance. As is well known, water was resolved into its elements as late as 1766, the elements composing the atmosphere were discovered in 1774, and the phlogiston theory was disposed of in 1785.

How crude the notions concerning the chemical nature of volatile oils were even at the time of Scheele, is shown in a dissertation¹⁾ of the year 1765 accepted by the University of Jena. From it the following propositions or conclusions are quoted:

"The essential constituents of volatile oils are of two kinds, solid and liquid. To the first class belong sulphur, phlogiston, earth and salts; to the second class air, fire and water. The presence of the first is revealed by the inflammability of the oils, for every object that burns with a flame contains much sulphur or phlogiston. The color as well as the coloration of the oil likewise argue in favor of their presence. Some oils are yellow, others green or blue; with age, the colors become darker. As is known, all coloration is due to particles of sulphur or phlogiston. Such oils have a penetrating odor, which is caused by their content of volatile saline sulphur particles. They, therefore, contain sulphur or phlogiston in sufficiently large quantities.

"In the course of time these oils are converted into a resinous mass, a change that is not conceivable without phlogiston.

"Volatile oils always burn with a smoking flame. All soot, however, consists of earth, salt, water and phlogiston. When the oils are treated with nitric acid, a residue of earth and carbon remains.

"Some volatile oils have a higher specific gravity than water. This is due to their larger content of earthy constituents and salts."

1752. *De oleis essentialibus æthereis eorumque modo operandi et usu.* Dissertatio ab Joh. Friedr. Vangerow. Hallæ.

1759. *De oleis destillatis æthereis.* Dissertatio ab Fr. W. Eiken. Helmstadii.

1765. *De partibus oleorum æthereorum constitutivis.* Dissertatio ab Johannes Christ. Schmidtius. Jenæ.

1765. *De partibus oleorum æthereorum constitutivis.* Dissertatio ab J. Fr. Faselius. Jenæ.

1765. *De oleis vegetabilium essentialibus, eorumque partibus constitutivis.* Dissertatio ab W. B. Trommsdorff. Erfurti.

1778. *De adulterationibus oleum æthereorum.* Dissertatio ab K. W. Chr. Müller. Göttingen.

¹⁾ *De partibus oleorum æthereorum constitutivis.* Dissertatio inauguralis per Johannes Christianus Schmidtius. Jenæ d. 30. März 1765.

Only a superficial insight into the nature of the volatile oils was obtained through the study of their properties and their behaviour toward strong chemical reagents, a study that was taken up at the beginning of the 18. century. Indeed, many of these experiments yielded no results whatever. This is true e. g. of the repeated distillations of volatile oils with chalk¹⁾ and burned lime, such as were undertaken by the otherwise excellent chemist Wilhelm Homberg (born 1652, died 1715) about the year 1700.

A better knowledge was attained by careful observation. Thus the crystalline deposits formed in some oils upon standing, also the congealing of certain oils at lower temperatures, which had been observed by Valerius Cordus in 1539, by Joh. Kunkel in 1685, by J. H. Link in 1717, by Friedr. Hoffmann in 1701, by Caspar Neumann in 1719 and by others, were studied. The crystalline parts were regarded as a volatile salt, later as a camphor peculiar to each oil, at times also as benzoic acid.²⁾ Fr. Hoffmann explained the congealing of oils of rose, anise and fennel by assuming the formation of a curdled modification of the oil. Caspar Neumann in 1719 and Cl. J. Geoffroy in 1726 regarded the crystals formed upon standing as camphor.³⁾ The formation of such crystals was observed by Caspar Neumann⁴⁾ in the oils of thyme, cardamom and marjoram; in peppermint oil by H. D. Gaubius⁵⁾ of Leyden in 1770; in oil of mace by J. G. Wiegler⁶⁾ in 1774; in the oils of lavender, rosemary, sage and marjoram by Arczula⁷⁾ in 1785. They regarded these

¹⁾ *Mémoires de l'académie royale des sciences de Paris.* 1700, p. 298 and 1701, p. 129, also *Chem. u. hotan. Abhandlungen der Acad. d. Wissensch. zu Parris.* Translated by Steinwehr. Vol. 3, pp. 155—157.

²⁾ Hagen, *Dissertatio chemica inauguralis sistens dosimasiam, concretionum in nonnullis oleis æthereis observatarum.* Regiomontanæ 1748.

P. J. Macquer's *Dictionnaire de Chymie.* Paris 1766. *Deutsche Übersetzung von* J. G. Leonhardi. Leipzig 1781. Vol. 4, p. 465, footnote 9.

³⁾ *Mémoires de l'académie royale des sciences de Paris.* 1726. p. 95.

⁴⁾ *De salinis alcalino lixis camphora.* Berolini 1727. p. 105.

⁵⁾ *Adversariorum varii argumenti liber unus.* Leidæ 1771. Sectio 7, p. 99—112.

⁶⁾ Vogel's *Lehrsätze der Chemie. Mit Anmerkungen herausgegeben von* J. G. Wiegler. Weimar 1775. § 342.

⁷⁾ *Resultato de las experiencias hechas sobre alcanfor de Murcia con licencia.* En Segovia 1789.

separations as varieties of camphor, only J. G. Wiegleb thought them to be peculiar combustible salts.¹⁾

The action of strong acids had been observed by Glauber²⁾ as early as 1663. The effect of strong nitric acid on a number of distilled oils was studied by Olaus Borrichius³⁾ in 167f, by J. P. Tournefort⁴⁾ in 1698, by Hasse⁵⁾ in 1783; that of sulphuric acid by Joh. Kunkel⁶⁾ in 1700 and by W. Homberg⁷⁾ in 1701. A more detailed study of the action of strong acids on volatile oils was made by Friedrich Hoffmann⁸⁾ and by Cl. J. Geoffroy⁹⁾ in 1726 and by Rouelle¹⁰⁾ in 1747. Upon distillation of oils with strong hydrochloric acid, especially if the acid was generated in an almost anhydrous condition in the experiment, it was supposed that compounds of the oil with the acid were obtained. Such a supposed compound was known to Homberg¹¹⁾ as early as 1709. The preparation, however, of such a compound of definite chemical composition was first accomplished by Kindt¹²⁾ an apothecary in Eutin, in 1803 by the action of gaseous hydrogen chloride on turpentine oil.

The solubility and color of distilled oils also received attention during the eighteenth century. Thus Macquer in 1745 published his investigations on the solubility of distilled oils in alcohol, which were the most extensive on this subject.¹³⁾ The color of oils and the changes in color were studied by Wilh. Homberg¹⁴⁾ in

¹⁾ See p. 74, footnote 6.

²⁾ R. Glauberii *Prosperitas Germaniz*. Amstelod. 1656.

³⁾ *Acta medica et philosophica Hallnienses*. 1671. p. 133.

⁴⁾ *Historia regiz scientiarum academiz. Autore du Hamel*. Parisii 1701. p. 495.

⁵⁾ Crell's *Neueste Entdeckungen in der Chemie* 9 (1783), 38. — Crell's *Chem. Annalen* 1 (1785), 417.

⁶⁾ *Laboratorium chymicum*. Hamburg 1716. p. 347.

⁷⁾ *Chem. botan. Abhandlungen der königl. Acad. d. Wissensch. in Paris*. Translated by Steinwehr. 1, 720.

⁸⁾ *Observatorium physico-chimicarum selectionum*. 1712. Liber III, p. 123.

⁹⁾ *Mémoires de l'académie royale des sciences de Paris*. 1726, 95.

¹⁰⁾ *Ibidem*. 1747, 45.

¹¹⁾ *Chem. botan. Abhandl. d. königl. Acad. d. Wissensch. in Paris*. Translated by Steinwehr. 3, 155--167.

¹²⁾ Trommsdorff's *Journ. d. Pharmacie* 11, II. (1803), 132.

¹³⁾ *Mémoires de l'académie royale des sciences de Paris*. 1745, 4.

¹⁴⁾ *Chem. botan. Abhandl. d. königl. Acad. d. Wissensch. in Paris*. Translated by Steinwehr. 3, 155--167.

1707 and by Jacob J. Bindheim¹⁾ of Moscow in 1788. The latter arrived at the conclusion that the color depends on a larger or lesser amount of resin carried over in the process of distillation, hence the darker colored oils are apt to contain considerable resin. Bindheim also determined the yield of oils, especially of those of chamomile and peppermint, by distilling larger amounts of these herbs.

In 1793 and 1794 Margueron studied the action of frost on volatile oils and observed the formation of crystals and congealing in connection with a number of the more common oils.²⁾

As has already been pointed out, the phlogistic theory afforded no satisfactory basis for the study of organic substances and consequently of volatile oils. With the discovery of oxygen by Scheele and Priestley during the years 1771³⁾ to 1774 and the ingenious interpretation of this and other discoveries by Lavoisier with the aid of the balance, a reaction against the phlogistic theory set in which resulted in the inauguration of the present chemical period. The study of the chemical constitution of substances was placed on a rational scientific basis. Inorganic chemistry, having to deal with the simpler substances, profited first by the new theories of the opponents of the phlogistic school. Organic chemistry, and with it the study of the volatile oils, were benefited somewhat later.

Though of little consequence, the experience of the Dutch chemists Deimann, Troostwyck, Bond and Lauverenhurg⁴⁾ should here be mentioned. They passed the vapors of volatile oils through red hot iron tubes and examined the resulting gases. At the same time they made the bold attempt to synthesize oils by the action of gaseous hydrogen chloride on olefiant gas.

The first investigation suggested by the new theories that was of positive value, was the elementary analysis of turpentine oil

¹⁾ Crell's Chem. Annalen. 1785, II. 219 and 488.

²⁾ Journ. de Chim. et de Phys. 2 (1794) 178. — Crell's Chem. Annalen. 1795, II. 195, 310 and 430.

³⁾ A. E. von Nordenskiöld, Scheele's *nachgelassene Briefe und Aufzeichnungen*. Stockholm 1892. pp. XXI, 86, 408, 458 and 466. — Pharm. Rundschau (New York) 11 (1893), 28 and 48.

⁴⁾ Journ. de Chim. et de Phys. 1794, II. 178. — Crell's Chem. Annalen. 1795, II. 195, 310 and 430.

made by Houtton-Labillardière.¹⁾ He found the ratio of carbon to hydrogen to be five to eight, the same that was later established for all hemiterpenes, terpenes, sesquiterpenes and polyterpenes.

Attention has already been called to the crystalline deposits that had been observed in the course of several centuries. These were mostly considered as identical with ordinary camphor because like it they were volatile, soluble in alcohol and fatty oils, and burned with a smoky flame. Only in a few instances, however, had these deposits been proven to be identical with camphor. Berzelius,²⁾ therefore, argued against the indiscriminate generic use of the term camphor.

"Several writers have applied the term camphor to all solid volatile oils. Thus a well known term of a commonly used substance has been given a different meaning from the one of long standing. Because of this disadvantage I felt myself constrained to disregard entirely this use of the word camphor."

In its place he suggested the use of the term stearoptene (from *σταίον*, tallow, and *αἴθρην*, volatile). He pointed out the analogy existing between volatile and fatty oils in so far as they can be a mixture of several oils having different congealing points. Thus oils may, under favorable circumstances, be separated into an oil which is solid at ordinary temperature, the stearoptene, and one which is liquid at low temperatures, the elaeptene (from *ἐλαίον*, oil, and *αἴθρην*, volatile.³⁾

The result of this was that the solid deposits from volatile oils were thereafter designated alternately stearoptene as well as camphor. Up to this day the misuse of the term camphor has not ceased as becomes apparent from such words as cedar camphor, cubeb camphor, juniper camphor, etc.

Soubéiran and Capitaine¹⁾ made matters even worse by applying the term "liquid camphor" to the liquid hydrogen-chloride addition products of the terpenes. After it had been shown that true camphor contained oxygen, the term camphor in its generic sense was also applied to other oxygenated constituents of volatile oils though they were liquid.

¹⁾ Journ. de Pharm. 4 (1818), 5.

²⁾ Berzelius, *Lehrbuch der Chemie*. 3. ed. 1837. vol. 6, p. 580.

³⁾ Berzelius, *Lehrbuch der Chemie*. 3. ed. 1837. vol. 6, p. 580.

¹⁾ Liebig's Annalen 34 (1840), 311.

In 1833 Dumas published an article entitled *Über die vegetabilischen Substanzen, welche sich dem Campher nähern und über einige ätherische Öle.*¹⁾ Although a number of important observations of rather striking properties of individual oils had been made, the systematic study of the volatile oils may be said to have begun with the analysis of a number of stearoptenes by Dumas. He suggested the following classification of volatile oils:

1. Those that consist of carbon and hydrogen only, like turpentine oil and oil of lemon;
2. Those that contain oxygen, like camphor and anise oil;
3. Those that contain sulphur,²⁾ like mustard oil, or nitrogen, like oil of bitter almonds.

The elementary analysis of solid peppermint oil, camphor and solid anise oil revealed the composition $C_{15}H_{26} \cdot \frac{1}{2}O$, $C_{15}H_{14} \cdot \frac{1}{2}O$ and $C_{15}H_{16} \cdot \frac{1}{2}O$. By doubling these formulas of Dumas the modern formulas for the respective substances are obtained.

Of the oxygen-free oils, he analyzed turpentine oil and the hydrocarbons of lemon oil, verifying the earlier results of Houtton-Labillardière. During the years 1833—1835, Dumas published further contributions on the subject of volatile oils, several jointly with Pelouze and Peligot. They pertain to artificial camphor (pinene hydrochloride), mustard oil, cinnamon oil, terpin hydrate, orris oil, pepper oil, oil of juniper berries and others.

Almost simultaneously with the first publications by Dumas, Blanchet and Sell³⁾ published the results of their investigation which had been carried out in Liebig's laboratory and which involved in large part the same substances studied by Dumas. The most noteworthy result of these investigations is the recognition of the identity of the stearoptene from fennel oil with that from anise oil.

Several years later, in 1837, the highly important and very

¹⁾ Liebig's Annalen 6 (1833), 245.

²⁾ The fact that mustard oil contains sulphur was recognized by Thibierge in 1819 (Journ. de pharm. 3, pp. 20, 439 and 446; Trommsdorff's Neues Journ. d. Pharm. 4, II. p. 250). That sulphuretted hydrogen is given off during the distillation of several umbelliferous fruits, such as caraway, dill, fennel, etc., was pointed out by L. A. Planche of Paris in 1820. (Trommsdorff's Neues Journ. d. Pharm. 7, I. p. 356.)

³⁾ Liebig's Annalen 7 (1833), 154.

interesting results of Liebig and Wochler's work on bitter almond oil were published.¹⁾ As early as 1802 Schrader and Vauquelin had discovered hydrocyanic acid in the distillate of bitter almonds. In 1822 Robiquet showed that no volatile oil preexisted in the almonds, and with Boutron-Charlard he had prepared amygdalin in 1830. They had not succeeded, however, in preparing bitter almond oil from amygdalin. That amygdalin is decomposed by emulsin into benzaldehyde, hydrocyanic acid and sugar was demonstrated by Liebig and Wochler. They also point out that the manner of formation of mustard oil must be closely related to that of bitter almond oil, for the mustard seeds deprived of their fatty oil possess no odor, this being produced only when water is present. The investigation of mustard oil by Will²⁾ in 1844 substantiated this supposition.

Chemists now became especially interested in the action of hydrogen chloride on various terpenes and in the resulting hydrochlorides, some of which were solid, others liquid; also in the study of terpin hydrate and its decomposition products. The study of the literature pertaining to these subjects is rendered difficult by the error of regarding mixtures of several substances as chemical individuals and describing them as such;³⁾ further by the fact that almost every author, irrespective of the work of others, coined a nomenclature of his own.⁴⁾

Crystalline pinene monohydrochloride had been discovered by Kindt,⁵⁾ an apothecary, in 1803. He regarded it as artificial camphor, a view shared by Trommsdorff.⁶⁾ The true composition of this compound was ascertained by Dumas in 1833.

¹⁾ Liebig's *Annalen* 22 (1837), 1.

²⁾ Liebig's *Annalen* 52 (1844), 1. A more complete insight into the mechanism of the reaction by which mustard oil is produced was supplied by the later investigations of Will and Koerner in 1863. Liebig's *Annalen* 125 (1863), 257.

³⁾ This confusion continued until Wallach cleared up the situation.

⁴⁾ The historical development of this chapter of the chemistry of the terpenes is described in *Terpene und Terpenoderivate, ein Beitrag zur Geschichte der ätherischen Öle* by E. Kremer's (*Pharm. Rundschau* 9 (1891), 55, 110, 159, 217, 237; and 10 (1892), 10, 31, 60; also *Proc. Wisc. Acad. Sc. Arts and Letters*, 8, pp. 312-262).

⁵⁾ Trommsdorff's *Journ. d. Pharm.* 11, II. 132.

⁶⁾ *Ibidem*, p. 135.

Crystalline dipentene dihydrochloride was discovered by Thenard in 1807. It is the *salzsaures Citronenöl*, muriate of lemon oil, of Blanchet and Sell, the artificial lemon camphor of Dumas. These and similar substances were investigated by Soubeiran and Capitaine (turpentine oil), Deville (turpentine oil and elemi oil), Schweizer (carvene) and Berthelot (turpentine oil).¹⁾ The formation of terpin hydrate and the action of acids on this substance was studied principally by Wiggers, List, Deville and Berthelot.²⁾

A paper published about this time (1841) by Gerhardt and Calours³⁾ is of special interest in so far as it contains a definition of a volatile oil which in a general way holds good to-day. It also makes known new methods of investigation. About oils in general the authors state:

"There are, indeed, but very few oils which can be crystallized; most oils are liquid and consist of a mixture of two and even three peculiar substances, which rarely are obtained by themselves when distilled at different temperatures."

The separation of the individual substances is effected by first allowing any solid constituent to crystallize out, then the lower boiling hydrocarbon is isolated by distillation at a temperature 20–30° below the boiling point of the crude oil.⁴⁾ Inasmuch, however, as the hydrocarbon cannot be completely freed from oxygenated constituents in this manner it is treated with fused alkali. The oxygenated constituents also are subjected to like

¹⁾ Of later investigators of this subject Oppenheim (1864), Heff and Ritter (1884), Bouchardat and Lafont (1886), and finally Walfach (1884–1887) may be mentioned.

²⁾ The same subject was later investigated by Oppenheim (1864), Hawitzky (1879), Tilden (1878–79), Bouchardat and Voisy (1887). Here also Walfach's exact investigations revealed the fact that different acids, as well as the same acid in different degrees of concentration, produce different results.

³⁾ Liebig's *Annalen* 38 (1841), 67.

⁴⁾ Fractional distillation, however, had been previously employed in the examination of volatile oils. As early as 1838 Wafer had subjected peppermint oil to interrupted distillation, *gebrochene Destillation* (Gmelin, *Handbuch d. Chem.* [4], vol. 7a, p. 404). In 1840 Volckel (Liebig's *Annalen* 33, 306) speaks of "fractional distillation." Already Blanchet and Sell in 1833 had applied fractionation with water vapor as a means of separation and had found that the first fraction of lemon oil boiled at 167°, the last fraction at 173°.

treatment with fused alkali, and cuminal oil is thus made to yield cuminal acid, oil of valerian, valeric acid.

Strong reagents were also employed by Rochleder, Persoz, Laurent and Gerhardt in order to obtain an insight into the nature of volatile oils. They oxidized either the entire oil or fractions thereof with chromic acid or nitric acid. Their investigations included the oils of valerian, sage, anise, staranise, fennel, cuminal, cinnamon, tansy and estragon. The conclusions drawn from these oxidation experiments were in part correct, in part wrong. Thus e. g. Gerhardt pointed out the identity of dragonic acid, obtained from estragon oil, with anisic acid, and claimed that estragon oil and anise oil were absolutely identical. This conclusion was wrong, for the anethol of anise oil is paramethoxypropenylbenzene, whereas the formation of anisic acid from estragon oil is due to the presence of paramethoxyallylbenzene.¹⁾

Moreover, this method rendered it impossible to decide whether a substance obtained after the oxidation preexisted in the oil or not. Thus camphor was found in several oxidized oils and was regarded as an original constituent although, as was the case in the oils of valerian and sage, it had resulted from borneol. Persoz, however, seems to have had doubts as to the reliability of these conclusions, for he leaves it undecided whether the camphor obtained from oil of tansy was contained in the oil or not. As a matter of fact, tansy oil contains camphor as an original constituent,²⁾ this being less readily attacked by the oxidizing agents than the other constituents of the oil.

Of considerable importance in the further development of the chemistry of volatile oils are the investigations of Berthelot from 1852 to 1863, which involve principally the hydrocarbons contained in these oils. He studied first of all the hydrocarbon of turpentine oil³⁾ and its isomers and polymers obtained from its hydrochloride. By heating pinene hydrochloride with barium stearate or sodium benzoate he obtained a new hydrocarbon which he

¹⁾ This difference was first ascertained in the laboratory of Schimmel & Co. (Report of Schimmel & Co. April 1892, 30) and verified by Grimaux in 1893 (Compt. rend. 117, 1189).

²⁾ Report of Schimmel & Co. October 1896, 46.

³⁾ Compt. rend. 55 (1862), 496 and 544; also Liebig's Annalen, Suppl. II. (1862-63), 226.

regarded as "camphene proper"¹⁾ and which is identical with the camphene of to-day. This new camphene was either dextrogyrate, lævogyrate or optically inactive according to the turpentine oil employed. Berthelot, therefore, distinguished between the following hydrocarbons:

1. *Terebentene* (*l*-pinene) from French turpentine oil, lævogyrate²⁾ b. p. 161°. It yields a lævogyrate monohydrochloride, also under proper conditions an inactive dihydrochloride (dipentene dihydrochloride).
2. *Terecamphene* (*l*-camphene) from terebentene hydrochloride, lævogyrate, m. p. 45°, b. p. 160°. With hydrogen chloride it forms a dextrogyrate hydrochloride.
3. *Australene* (*d*-pinene) from American turpentine oil, b. p. 161°, dextrogyrate like its hydrochloride. Its behavior to hydrogen chloride is analogous to that of terebentene.
4. *Austracamphene* (*d*-camphene) from australene hydrochloride. It corresponds to terecamphene.
5. *Inactive camphene* (*i*-camphene) can be obtained by proper treatment from the hydrochloride of terebentene as well as that of australene.
6. *Terebene*,³⁾ b. p. 160°.

These six hydrocarbons are isomeric and have the formula $C_{10}H_{16}$. With these the following are polymeric:

1. A liquid hydrocarbon boiling at 250° which is probably a sesquiterbene, $C_{15}H_{24}$.
2. Diterbene (Deville's colophene) $C_{20}H_{32}$, an inactive liquid boiling at about 300°.
3. Several polyterebenes $C_{30}H_{48}$, optically inactive liquids becoming more and more viscid, which boil between 360° and a dark red heat.

After a discussion of the methods of formation of the individual hydrocarbons, Berthelot continues:

¹⁾ Soubeiran and Capitaine in 1840 had applied the term camphene to all hydrocarbons $C_{10}H_{16}$ (Liebig's Annalen 34, 311).

²⁾ The rotatory power of volatile oils was first observed by Biot in 1817 in connection with French oil of turpentine (Mémoires de l'Acad. des Sc. 13), later also with oil of lemon. The turpentine oil was shown to be lævogyrate, the oil of lemon dextrogyrate. In 1843, Leeson of London found that American turpentine oil possessed a rotatory power opposite to that of the French oil. This observation was soon after verified by Pereira and Guibourt. Pereira introduced the terms lævo-gyrate and dextro-gyrate (Pharm. Journ. 5 [1845], 70).

³⁾ This substance which was considered a chemical unit by Berthelot was shown by Rihaan to be a mixture of a terpene, cymene and camphor. Power and Kleber in 1894 found camphene, dipentene, terpinene and cymene in terebene. (Pharm. Rundsch. 12 [1894], 16.)

In accordance with the known facts, the hydrocarbon $C_{10}H_{18}$ — e. g. terebentene — may be regarded as the starting point of two series:

1. Of a monatomic or camphol¹⁾ series (monohydrochlorides or chlorine esters of camphol, $C_{10}H_{17}Cl$; camphene, $C_{10}H_{16}$; camphol alcohols, $C_{10}H_{18}O$);
2. Of a diatomic or terpil series (dihydrochlorides, $C_{10}H_{16}Cl_2$; terpilene, $C_{10}H_{16}$; hydrate $C_{10}H_{16}O_2$).

Each of these two series constitutes a larger group, which can be divided into secondary series (australene, terebentene, etc.) the parallel and isomeric members of which occur in twos; each has as type an inactive hydrocarbon, namely camphene in the first group, terpilene in the second.

A similar, but much less detailed classification was attempted by Gladstone²⁾ in 1864, after having determined the specific gravity, the index of refraction and the optical rotation of a number of oils. By means of fractional distillation he isolated the hydrocarbons of various oils, rectified them by distillation over sodium and arranged them into three large groups:

1. Hydrocarbons of the formula $C_{10}H_{18}$ which boil between $160-170^\circ$;
2. Hydrocarbons of the formula $C_{15}H_{24}$ which boil between $249-260^\circ$;
3. Colophene, $C_{20}H_{32}$, b. p. 315° , representing the third group.

About this time the word terpene was introduced, evidently by Kekulé. In his *Lehrbuch der organischen Chemie* (1866) vol. 2, p. 437, the following statement occurs:

"... andererseits das Terpentinöl und die zahlreichen mit ihm isomeren Kohlenwasserstoffe, welche im allgemeinen als Terpene bezeichnet werden mögen."

His investigations, preceded by those of Barbier and Oppenheim were of considerable importance, inasmuch as by revealing the relations between the terpenes and cymene, they threw new light on the molecular structure of these hydrocarbons.

Almost simultaneously Barbier³⁾ and Oppenheim⁴⁾ obtained cymene by heating the dihydride of terpin either by itself or with aniline. By the action of iodine on turpentine oil, Kekulé⁵⁾ obtained the same hydrocarbon. He, therefore, thought himself

¹⁾ Berthelot changed the name borneol to camphol. Liebig's Annalen 110 (1859), 368; from Compt. rend. 47 (1858), 266.

²⁾ Journ. chem. Soc. 17 (1864), 1. A second contribution appeared eight years later. *Ibidem*, 25 (1872), 1.

³⁾ Compt. rend. 74 (1872), 194.

⁴⁾ Berl. Berichte 5 (1872), 94.

⁵⁾ Berl. Berichte 6 (1873), 437.

justified in supposing six atoms of the turpentine oil to be arranged in similar manner as in benzene. Further, that the methyl and propyl groups in the turpentine oil occupy the same relative positions as in cymene.¹⁾

This view of the constitution of the terpenes was the predominant one for a long time. It is only recently that researches have revealed facts not in harmony with this view. With this the question of the constitution of the terpenes had its origin. Important in this direction was also the synthesis of a terpene — the polymerization of isoprene to dipentene -- by Bouchardat²⁾ in 1875.

In the same year, Tilden³⁾ found that the hydrocarbon of turpentine oil combines with nitrosylchloride to form a well crystallizing compound. Together with Stenhouse, he applied this reaction to the terpenes from the oils of sage, orange, lemon and bergamot. On the behavior of these hydrocarbons to nitrosylchloride he based a new classification, concerning which he makes the following statement:

"The natural terpenes are colorless limpid liquids which vary in specific gravity from about 0.84 to about 0.86. They are divisible into two groups as follows: —

1. Turpentine group: h. p. 156° to 160°; m. p. of nitroso-derivative 129°; form solid crystalline hydrated terpin $C_{10}H_{16}O_2 \cdot H_2O$.
2. Orange group: b. p. 174° to 176°; m. p. of nitroso-derivative 71°; form (by Wigger's process) no solid crystalline terpin hydrate.⁴⁾

The liquids included in each group are allotropic modifications of the same hydrocarbon distinguished one from another by their various rotatory action on the polarized ray. It will, however, be found I believe that the terpenes from several different plants will on further examination be conclusively proved to be really identical and not simply isomeric. This, I believe, to be the case with the terpenes from French turpentine and sage, also with the terpenes from orange peel, bergamot and lemon."

Tilden's prediction, that the number of terpenes would be shown to be much smaller than assumed in his days, has proven

¹⁾ Kekulé's formula for camphor was based on the same consideration.

²⁾ Compt. rend. 80 (1875), 1446.

³⁾ Journ. chem. Soc. 28 (1875), 514; *Ibidem*, 31 (1877), 554; Pharm. Journ. III. 8 (1877), 191.

⁴⁾ This statement is incorrect, for dipentene and limonene likewise produce terpin hydrate. Comp. Flückiger, Arch. der Pharm. 222 (1884), 362; also Kremers, Americ. chem. Journ. 17, 695.

itself true. His classification, however, was insufficient, for it included only a small number of terpenes. Indeed the material at hand was not sufficiently sifted for an attempt of that kind. It consisted of a large number of disconnected observations, the study of which was rendered difficult by an arbitrary nomenclature. Only by a systematic exploration of this disorderly realm could a clear insight into the subject be gained.

That we are able to-day to distinguish sharply between so many terpenes and their derivatives is due primarily to the excellent experimental researches of Otto Wallach, the founder of modern terpene chemistry.

Inasmuch as it was impossible to isolate the numerous terpenes boiling between 155 and 185 by fractional distillation, methods had to be sought which enabled the characterization of these hydrocarbons, even in mixtures, by means of crystalline derivatives. Only after the characterization of the numerous isomers was accomplished was it possible to study successfully the relation of one terpene to another, the relation of the terpenes to their oxygenated derivatives, and the problem of their constitution.

These problems have been solved in so far that it is now possible to identify many if not most terpenes without great difficulty. The inversions, or changes from one to the other, are also better understood. The problem of their constitution, however, is still far from a satisfactory solution, though structural formulas have been proposed for a number of the terpenes.

In 1884 Wallach¹⁾ began his researches on this subject with the investigation of the oil of wormseed (*Oleum cinæ*). Three years later he was in a position to characterize eight terpenes by means of crystalline derivatives (tetrabromides, hydrochlorides, hydrobromides, nitrosites etc.), viz. pinene, camphene, limonene, dipentene, sylvestrene, terpinolene, terpinene and phellandrene.

¹⁾ Wallach's contributions are to be found in the following volumes of Liebig's Annalen: 225, 227, 230, 238, 239, 241, 245, 246, 252, 253, 258, 259, 263, 264, 268, 269, 270, 271, 272, 275, 276, 277, 278, 279, 281, 284, 286, 287, 289, 291, 296, 300, 302, 305, 306, 309, 312, 313, 314, 315, 319, 323, 324, 327, 329, 331, 332, 336, 339, 340, 343, 345, 346, 347, 350, 353, 356, 357, 359, 360. — Several papers from his pen are to be found in the Berl. Berichte 28 (1890) to 40 (1907).

To these fenchene was added later. The sesquiterpenes were also included in his investigations. Three of these were well characterized, *viz.*, cadinene, caryophyllene and clovene. The reactions that were applied were for the most part first studied in connection with simpler substances. Thus a series of contributions resulted including amylene, indene, methyldiene, anethol, isosafrol etc.

Hand in hand with these investigations, researches were conducted with the oxygen derivatives of the terpenes which have a greater capacity for reaction. Of these even less was known. Like the terpenes, they were characterized by crystalline derivatives.

The genetic relationship between the terpenes themselves and also that existing between the terpenes and the oxygenated constituents of the volatile oils was revealed by transforming the one into the other. These changes were of the greatest importance in the study of the chemical constitution of these compounds. Moreover, this study yielded numerous new compounds, among them such as methylheptenone, which are found in volatile oils. Mention may here be made of the relation existing between the terpenes, terpin hydrate and the terpineols; between the members of the carvone group; of cineol; and of the first synthetic oxide of a terpene, the pinol and its hydrate. Mention may also be made of the more recent work on terpinene, the terpinenol, terpinene terpin and terpinene cineol and their relation to sabinene and thujene. As a chapter by itself, mention should be made of the study of the camphor and fenchone groups, which were made possible by the discovery of the latter ketone and its optical isomers. These studies led to the preparation of numerous new derivatives as did also those connected with the discovery of thujone.

When the cleavage of pulegone made 1,3-methylheptenone a readily accessible substance, the study of alicyclic compounds resulted in a considerable number of papers. These substances are mostly closely related to the terpenes and their derivatives. Hence many a reaction was first studied in connection with these simpler substances in order to be applied later to the more complicated terpenes. These simpler substances, *e. g.* isopropyl hexenone, nopinone, sabinaketone having been obtained from other terpene derivatives, were in turn used for synthetic pur-

poses. In this connection methods of condensation were studied, especially those with brom substitution products of the fatty acids. Thus were accomplished the syntheses of menthene, phellandrene, terpinene, β -pinene, fenchene, and of homologues of the terpenes.

An important place in Wallach's researches is occupied by the successful efforts to unravel the isomeric complications so prevalent in the terpene group. Thus special investigations dealt with the study of optical isomerism, molecular refraction, cleavage of cycles as well as their formation, hydration and other physical and chemical problems.

After Wallach had removed the principal difficulties in the investigation of volatile oils, other chemists also developed a successful activity. A. v. Baeyer's valuable investigations into the constitution of the terpenes and related compounds appeared in the *Berichte der deutschen chemischen Gesellschaft* since 1893.

Whereas Wallach and v. Baeyer investigated primarily the cyclic compounds, Semmler paid special attention to chain compounds. He showed that the alcohols geraniol and linalool and the aldehydes citral and citronellal, which occur frequently in volatile oils, are chain compounds; also that they, like the more or less closely related cyclic compounds, can be converted into cymene. Later, Semmler's activity extended to practically all fields of volatile oil and terpene chemistry. Of the terpenes he examined sabinene, camphene, phellandrene, camphenilone. Among other problems, Semmler cleared up the constitution of buchu camphor, of santalol and of myrtenol. To him we are also indebted for our knowledge of the constituents of the oils of asarum, of East Indian sandalwood, of pilea oil, ayapana oil, etc. Practically all of his results have been published in the *Berichte der deutschen chemischen Gesellschaft*.¹⁾

In this connection the work of Tiemann and his collaborators, which began with the nineties of the past century, should be mentioned. This included the isolation of irone, the principal constituent of orris oil; later this led to the synthesis of ionone, which possesses the aroma of the violet. In this connection he published numerous articles on the chemistry of citral.

¹⁾ Berl. Berichte 23 (1890) to 41 (1908).

To these fenchene was added later. The sesquiterpenes were also included in his investigations. Three of these were well characterized, *viz.*, cadinene, caryophyllene and clovene. The reactions that were applied were for the most part first studied in connection with simpler substances. Thus a series of contributions resulted including amylene, indene, methyldiene, anethol, isosafrol etc.

Hand in hand with these investigations, researches were conducted with the oxygen derivatives of the terpenes which have a greater capacity for reaction. Of these even less was known. Like the terpenes, they were characterized by crystalline derivatives.

The genetic relationship between the terpenes themselves and also that existing between the terpenes and the oxygenated constituents of the volatile oils was revealed by transforming the one into the other. These changes were of the greatest importance in the study of the chemical constitution of these compounds. Moreover, this study yielded numerous new compounds, among them such as methylheptenone, which are found in volatile oils. Mention may here be made of the relation existing between the terpenes, terpin hydrate and the terpineols; between the members of the carvone group; of cineol; and of the first synthetic oxide of a terpene, the pinol and its hydrate. Mention may also be made of the more recent work on terpinene, the terpinenol, terpinene terpin and terpinene cineol and their relation to sabinene and thujene. As a chapter by itself, mention should be made of the study of the camphor and fenchone groups, which were made possible by the discovery of the latter ketone and its optical isomers. These studies led to the preparation of numerous new derivatives as did also those connected with the discovery of thujone.

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also a very meagre description of the physical properties of the oils and their behavior toward reagents. Maier's¹⁾ later treatise also takes into consideration the scientific investigations. The methods of preparation and the subject of distillation are described in detail by Mierzinski.²⁾ A similar work was written by Askinson.³⁾ *Die Toiletten-Chemie* of Hirzel,⁴⁾ which passed through four editions, also "The art of perfumery" by Piesse,⁵⁾ which was translated into several languages, may here be mentioned.

The results of the earlier papers by Wallach are contained in the excellent work of Bornemann,⁶⁾ whereas the *Odorographia* of Sawyer⁷⁾ emphasizes the botanical side of the subject.

Indispensable to scientific work on the chemistry of the terpenes was the monograph of F. Heusler⁸⁾ which comprises the otherwise scattered literature up to the close of the last century. Translated into English by F. J. Pond⁹⁾ and supplemented, it was published in the U. S. in 1892. Restricted to the sesquiterpenes is the smaller monograph by O. Schreiner.¹⁰⁾

Shortly after the appearance of *Die ätherischen Öle* by E. Gildemeister and Fr. Hoffmann, a similar work in French was published by Charabot, Dupont and Pillet,¹¹⁾ another in English by E. J. Parry.¹²⁾

¹⁾ Dr. Julius Maier, *Die ätherischen Öle, ihre Gewinnung, chemischen und physikalischen Eigenschaften, Zusammensetzung u. Anwendung*. Stuttgart 1867.

²⁾ Dr. Stanislaus Mierzinski, *Die Fabrikation der ätherischen Öle und Riechstoffe*. Berlin 1872.

³⁾ Dr. George William Askinson, *Die Fabrikation der ätherischen Öle*. Wien 1876.

⁴⁾ Dr. Heinrich Hirzel, *Die Toiletten-Chemie*. Leipzig 1864 and subsequent editions.

⁵⁾ S. Piesse, *The Art of Perfumery*. London 1862 and subsequent editions.

⁶⁾ Dr. Georg Bornemann, *Die flüchtigen Öle des Pflanzenreichs, ihr Vorkommen, ihre Gewinnung und Eigenschaften, ihre Untersuchung und Verwendung*. Weimar 1891.

⁷⁾ J. Ch. Sawyer, *Odorographia*. London 1892-1894.

⁸⁾ Dr. Fr. Heusler, *Die Terpene*. Braunschweig 1896.

⁹⁾ The Chemistry of the Terpenes by F. Heusler. Authorized Translation by Francis J. Pond. Carefully revised, enlarged and corrected. Philadelphia 1902.

¹⁰⁾ O. Schreiner, *The Sesquiterpenes. A Monograph*. Milwaukee 1904.

¹¹⁾ E. Charabot, J. Dupont et L. Pillet, *Les huiles essentielles et leurs principaux constituants*. Paris 1899.

¹²⁾ Ernest J. Parry, *The Chemistry of Essential Oils and Perfumes*. London 1899 and 1910.

Dealing primarily with artificial perfume materials, but also with natural products, the smaller works by J. M. Klimont,¹⁾ E. Charabot,²⁾ P. Jeancard and C. Satie,³⁾ G. Cohn⁴⁾ and R. Knoll⁵⁾ should be mentioned. O. Simon's⁶⁾ book deals exclusively with analysis.

Also indispensable to the terpene chemist working along scientific lines are the excellent treatises on related subjects by C. Harries⁷⁾ and O. Aschan.⁸⁾

Die ätherischen Öle is the title of a large four volume work by Semmler⁹⁾ published between 1905 and 1907. It is replete with references to original literature and treats of all substances found in volatile oils and might well have been labeled "Chemistry of the constituents of the volatile oils." Finally, there should be mentioned the recent French book on volatile oils by Durvelle.¹⁰⁾

This extraordinary growth of our knowledge of the volatile oils during the past twenty-five years has had a very stimulating effect on the practical development. Hence, parallel with the scientific development, the industry of volatile oils and artificial perfumes has to record a vigorous growth. Older factories, having outgrown their former quarters, had to be enlarged, and a number of new factories, both foreign and domestic were established.

The progress made in the investigation of the composition and properties of the volatile oils has resulted in a similar

¹⁾ J. M. Klimont, *Die synthetischen und isolierten Aromatica*. Leipzig 1899.

²⁾ E. Charabot, *Les Parfums artificiels*. Paris 1900.

³⁾ P. Jeancard et C. Satie, *Abrégé de la Chimie des Parfums*. Paris 1904.

⁴⁾ G. Cohn, *Die Riechstoffe*. Braunschweig 1904.

⁵⁾ R. Knoll, *Synthetische und isolierte Riechstoffe und deren Darstellung*. Halle 1908.

⁶⁾ O. Simon, *Laboratoriumsbuch für die Industrie der Riechstoffe*. Halle 1908.

⁷⁾ C. Harries, *Einkernige hydroaromatische Verbindungen einschließlich der Terpene und Campherarten. Erschienen im Lehrbuch der organischen Chemie* of Victor Meyer and Paul Jacobson. Leipzig 1902.

⁸⁾ O. Aschan, *Chemie der alicyclischen Verbindungen*. Braunschweig 1905.

⁹⁾ F. W. Semmler, *Die ätherischen Öle nach ihren chemischen Bestandteilen unter Berücksichtigung der geschichtlichen Entwicklung*. Leipzig 1906—1907.

¹⁰⁾ J. P. Durvelle, *Fabrication des Essences et des Parfums*. Paris 1908.

development of the analysis of these oils. Hence the pharmacopœial requirements concerning the volatile oils have become more specific and exacting. Not only are pure oils demanded, but such that are rich in active constituents. However, the great variation existing in the requirements of the several pharmacopœias, merely reveals the fact that the composition of these natural products as well as the variation to which they are subject, has not yet been sufficiently investigated. Hence the methods of testing still leave much to be desired. If this is true of the oils used medicinally, which as a rule are among the better known oils, this lack of knowledge is felt even more among the non official and lesser used oils. The recent rapid scientific and technical development of this field, however, justifies the hope that the present defects will be removed in the not distant future, and that problems still to arise will also be solved in a satisfactory manner.

III. HISTORY OF INDIVIDUAL VOLATILE OILS.

TURPENTINE OIL.

The oils obtained by the distillation of the oleoresins of various *Abietineæ* were known to the ancients as cedar oil (*αισθαλαυρον*)¹⁾ and later became known as turpentine oil. The oil as well as the resin, the colophonium, were used by seafaring people. The preparation of turpentine oil, as recorded by Dioscorides, is described in the next chapter. Taking into consideration the perfection of varnishes and lacquers employed by the Chinese, it may be supposed that coniferous oils were distilled and used by them. However this may be, the oils of the *Abietineæ* obtained in a crude manner have evidently been the first volatile oils that found commercial use and technical application.

The name turpentine oil seems to have been introduced during the period of Greek civilization. Like the older synonyms (cedar oil, etc.) it apparently was used as a collective term. It is of Persian origin,²⁾ and may have been derived from the name of the resinous exudation of the Cyprian species *Pistacia terebinthus*, L.

As far as is known to history, the preparation of turpentine oil probably had its origin in the Caucasus and its south-western spurs. In central Europe it became known during the middle ages, somewhat later also in northern Europe. The North American industry had its origin in the dense and extensive pine

¹⁾ Herodoti *Historiæ*. Lib. II, 85. — Dioscorides, *De materia medica*, Lib. I, 34, 39, 80. Editio Kühn-Sprengel 1829, I, 93. — Plinius, *Naturalis historiæ libri*, Lib. XV, cap. 6—7 and Lib. XVI, cap. 22.

²⁾ Flückiger, *Pharmakognosie*, 3rd ed., p. 77.

forests of the South Atlantic States and developed in the beginning of the eighteenth century especially in Virginia and Carolina.¹⁾

Inasmuch as the crude turpentine oil found little or no use in either household economy or in religious rites, it is but seldom mentioned in early literature. Attention has already been called on pp. 17, 29, 30, and 38 to mentionings by the older writers. Since its introduction into medicine, the mediaeval works on distillation and materia medica make mention of the oil. In addition to the references by A. Villanovus and R. Lullus, who lived in the thirteenth century, to which attention has been called on pp. 31 and 33, mention is made of oil of turpentine by the following writers of the fifteenth century: Saladinus of Aseulo²⁾ and the canon Johann of Santo Amando of Doornyk³⁾; during the sixteenth century by Walter Ryff,⁴⁾ Conrad Gesner,⁵⁾ Joh. Baptista Porta,⁶⁾ Valerius Cordus⁷⁾ and Adolphus Oeco.⁸⁾

Attention has already been called to the synonymous usage during the seventeenth century of the designations of alcohol and turpentine as *aqua ardens* and *spiritus*. The name *Spiritus*

¹⁾ Prof. Peter Kalm's *Reise nach dem nördlichen Nordamerika im Jahre 1748–1749. Göttinger Sammlung neuer und merkwürdiger Reisen zu Wasser und zu Lande*. 3 vol. Göttingen 1754. Vol. 2, pp. 418, 556; vol. 3, pp. 293, 305, 523.

Johann David Schöpf, *Reise durch einige der mittleren und südlichen Staaten von Nordamerika in den Jahren 1783–1784*. 2 vol. Erlangen 1787. Vol. 2, pp. 220, 223, 273.

F. A. Michaux, *Histoire des arbres forestiers de l'Amérique septentrionale*. Paris 1810.

²⁾ Saladini Asculani *Cumpendium aromatariorum*. Veneti 1488. Index.

³⁾ *Expositio* Janis de Santo Amando *supra antidotarii Nicolai incipit feliciter*. "*Oleum de terehinthina lit similiter per sublimationem, et est clarum ut aqua fontis . . . et ardet ut ignis græcus cum oleo benedicto etc.*" Turpentine oil is mentioned fol. 228b of the edition of 1589 already referred to on p. 25, footnote 2.

⁴⁾ Gualtherius Ryff, *New groß Destillirbuch wold gegründeter künstlicher Destillation*. Francofurti 1556, fol. 180.

⁵⁾ *Ein köstlicher theurer Schatz* Eonymi Philatri *darinnen enthalten sind vil heymlicher guter stück der artzney*. Editio 1555. Vol. 1, p. 238.

⁶⁾ Gio. Batt. Porta: *Magiæ naturalis libri viginti*. Editio 1589.

⁷⁾ *Dispensatorium Noricum*. 1546.

⁸⁾ *Pharmacopœa prœ Republica Augustana*. 1564.

terebinthinae has maintained itself as a popular term up to this time. As *huile ætherée* it seems to have been first designated in the year 1700.

The early observations made in connection with oil of turpentine concerned its behavior at low temperatures. As early as 1794 Margueron¹⁾ claims to have observed that the oil, when reduced to a temperature of -22° R. solidifies to a crystalline mass. Crystals had already been observed by Cl. Jos. Geoffroy in 1727 in the neck of the retort while distilling the oil. In conformity with the practice of designating as camphor all solid substances separating from volatile oils, these needle-like crystals, presumably pinol hydrate, were called turpentine camphor.

While making the so-called *Liquor antarthriticus Pottii*, in the preparation of which hydrogen chloride is passed into turpentine oil, the apothecary Kindt²⁾ of Eutin, in 1803 obtained a solid crystalline mass³⁾ which he considered to be artificially prepared camphor. This compound was examined by Gehlen⁴⁾ and by Dumas.⁵⁾ The first elementary analysis of the oil was made by Houton-Labillardière⁶⁾ in 1817. In the same year this oil served as the first volatile oil of which the angle of rotation was ascertained.

AMERICAN TURPENTINE OIL.

The enormous turpentine industry of the United States had its origin in the large pine forests of North and South Carolina, Georgia, and Alabama. Up to the middle of the last century the products of this industry were tar and pitch which were used principally in ship building and as naval supplies and hence were termed "naval stores".⁷⁾ The distillation of turpentine oil

¹⁾ Journ. de Chim. et de Phys. 2 (1794), 178. — Crelt's Chem. Annalen 1795, II, 195, 310 and 430.

²⁾ Trommsdorff's Journ. der Pharm. 11, II. (1803), 132.

³⁾ Pinemonochlorhydrate $C_{10}H_7Cl$.

⁴⁾ Gehlen's Allgem. Journ. für die Chemie 6 (1819), 462–469.

⁵⁾ Annal. de Chim. et Phys. II. 52 (1833), 400. — Liebig's Annalen 9 (1834), 56.

⁶⁾ Journ. de Pharm. II. 4 (1818), 5.

⁷⁾ The oldest mention concerning tar and pitch, and the preparation of turpentine in Virginia is to be found in vol. I of the "Calendar of State Papers. Colonial Series" for the year 1574 to 1660 in the Public Record

seems to have begun as late as the middle of the eighteenth century in North Carolina and Virginia. Professor Kalm, the Swedish traveler, who is known as a careful observer, and who explored the Atlantic provinces of the then British colonies from Quebec to Virginia during the years 1749 and 1750, reports concerning the preparation of tar and pitch only.¹⁾ Later travelers and reports first make mention of the preparation of turpentine, turpentine oil and colophony in Carolina. Among these are Dr. Johann David Schoepf, who traversed the Atlantic States from Canada to Florida²⁾ in 1783 and 1784; also François André Michaux, who about twenty years after the longer stay of his father, the well known botanist André Michaux, traveled in North America at the beginning of the nineteenth century.³⁾

Up to the year 1820 the consumption of turpentine, turpentine oil and colophony was restricted to the limited demands of the home industries. The exportation of oil and rosin to England was unimportant. Up to 1830 the manufacture of turpentine was restricted to the coast: between the Tar river in the north, and Cape Fair river in the south; while the ports New Bern, Wilmington and Washington in North Carolina served as collective points. The distillation of turpentine was conducted in cast iron stills.

At the beginning of the thirties the application of turpentine in the industries experienced considerable extension. This was caused primarily by the increased use of paints accompanying the increase in wealth; by the development of the varnish,

Office in London. Of the year 1610 this volume contains "Instructions for suche things as are to be sente from Virginia," also a printed pamphlet: "The Booke of the Commodities of Virginia." Both mention pitch, tar, rosin and turpentine among the products of Virginia. The former also contains brief directions for the method of preparation of turpentine which is still in vogue. (Dan. Hanbury, in *Proceed. Americ. pharm. Ass.* 19 [1871], 491.)

¹⁾ *Reise nach dem nördlichen Nordamerika im Jahre 1748 bis 1750 von Prof. Peter Kalm in Göttingsche Sammlung neuer und merkwürdiger Reisen zu Wasser und zu Lande.* Göttingen 1754—1764. Vol. 2, pp. 418, 474; vol. 3, pp. 305, 523.

²⁾ *Reise durch einige der mittleren und südlichen Vereinigten Nord-amerikanischen Staaten in den Jahren 1783 und 1784 von Dr. Johann David Schöpl.* Erlangen 1788. Vol. 2, pp. 141, 247 252.

³⁾ *Histoire des arbres forestiers de l'Amérique septentrionale, par F. André Michaux.* Paris 1810. Vol. 1, p. 73.

lacquer and caoutchouc industries; and, finally, by the use of a mixture of turpentine oil and alcohol as an illuminating agent, which had been introduced since 1839 as camphine and under other fanciful names. Up to the introduction of petroleum products (kerosene) about 1860, this was the cheapest illuminating material. The improvements, made in the course of the thirties, by Comstock, Hancock, Macintosh, Chaffee and especially by Luedersdorff in the processes employed in the caoutchouc industry did much to bring about a larger consumption of turpentine oil.

This increase in the consumption brought about an increase in the turpentine industry in 1834, and caused the introduction of better distilling apparatus such as copper stills which insured not only a larger yield of turpentine oil but also a better quality of resin.¹⁾ The exportation of American turpentine oil and colophony to England and other countries assumed large proportions only after the removal of the import duty in England in 1846. It was interrupted, however, during the years 1861 to 1865 of the civil war, the period of industrial and commercial stagnation.

Up to the year 1837, the opinion prevailed in Carolina that the pine forests farther to the south were not adapted to the production of turpentine on account of differences in climate and soil. In the year mentioned, experiments conducted on a large scale showed this opinion to be erroneous. As a result of the great demand and of increasing speculation, the industry spread rapidly to South Carolina and Georgia, and later to Alabama and Mississippi.²⁾ With the introduction of the more readily transportable copper stills, the distillation was more and more conducted at the place of production, so that the turpentine farms began to supply the finished though crude products of distillation, oil and rosin, in place of turpentine, to the ports along the coast. With the increased consumption of turpentine oil a corresponding overproduction of rosin resulted. This could

¹⁾ The forests, forest lands and forest products of Eastern North Carolina. By W. W. Ashe. Raleigh N. C. 1894.

²⁾ Carl Mohr, The timber pines of the Southern United States. Washington 1897. p. 69. -- *Die Gewinnung und Verarbeitung des Terpentins im Süden der Ver. Staaten.* Pharm. Rundschau (New York) 2 (1884), 187.

not be disposed of and consequently suffered a corresponding depreciation in value.

This disparity was equalized toward the end of the sixties. The opening up of new territories of production brought about an overproduction in turpentine oil as well, which was felt all the more because petroleum products took its place as an illuminating agent and also superseded it in various branches of the arts and industries. On the other hand, colophony found new and large application.

The turpentine industry in the Southern states thus developed more and more. With the establishment of cheap means of transportation by rail and by water, all the conditions were given for a prosperous growth to the enormous dimensions on which this industry is being conducted at present.

FRENCH TURPENTINE OIL.

The production of turpentine in southwestern France, from *Pinus pinaster*, Solander, must have been in progress at a very early period.¹⁾ At least this is the inference drawn from petrified trunks of trees, found along the coast, which reveal the wounds characteristic of the resin production. Later on, historic documents of 1382 and 1383 reveal that Richard II. of England gave permission to the Captal de Buch Archambault de Grailly to conduct resin markets within his territory. Probably the maritime pine was first planted as a protection to the dunes. After numerous failures, this plan proved a success only toward the end of the 18. century. The experiment to sow the seeds in the sand successfully tried by the engineer Brémontier is followed up to the present time by the government.

The method, still in use, to collect the resinous exudation in earthenware pots is attributed to Serres (1836) and Hugues (1840).

The distillation of turpentine oil is being conducted in France since 1783.²⁾

¹⁾ O. A. Oesterle, *Die Harzindustrie im Südwesten von Frankreich*. Berichte d. deutsch. pharm. Ges. 11 (1901), 217.

²⁾ Corps gras industriels 84 (1908), 179.

TURPENTINE OIL FROM VENETIAN (LARCH) TURPENTINE

Larch turpentine was known to the Romans. It is mentioned in the writings of Vitruvius,¹⁾ a contemporary of Cæsar, also in those of Dioscorides,²⁾ Pliny,³⁾ and Galen. During the middle ages, larch turpentine was one of the most highly prized balsams. The name Venetian turpentine was applied to it during the fifteenth century,⁴⁾ because it was brought into the market from Venice at that time the center of the drug commerce.

The first mention of larch oil (*Oleum laricis*) in medical treatises is found in the works of Matthioli⁵⁾ and Conrad Gesner.⁶⁾

TURPENTINE OIL FROM CANADA BALSAM.

Canada balsam, which was probably long known to the American Indians and employed by them, is first mentioned in European reports of travel by Marc Lescarbot⁷⁾ who traveled in Canada during the years 1606 and 1607. He declares the balsam equal in value to the Venetian. In the European market however, it is not found before the eighteenth century (Flückiger).⁸⁾

OIL OF CYPRESS.

Oil of cypress was known as early as 1672 (comp. p. 62). In 1892 it was recommended as a remedy against whooping cough by J. M. Bravo⁹⁾ and since 1894 it has been distilled by Schimmel & Co. on a commercial scale.¹⁰⁾ The experiences of Professor Dr. Soltmann in connection with a large number of patients of the chil-

¹⁾ Marcus V. P. Vitruvius, *De architectura*. Vol. 2, p. 9.

²⁾ Dioscorides, *De materia medica libri quinque*. Editio Kühn-Sprengel 1829, vol. 1, p. 45.

³⁾ Plinius, *Naturalis historie libri* 39. Littré's edition. Cap. XVI, 575.

⁴⁾ Flückiger, *Pharmakognosie*. 3rd edition, p. 80.

⁵⁾ Petri Andreae Matthioli *Opera quæ extant omnia*, edit. 1598, vol. I, p. 102.

⁶⁾ Eusebii Philatri *Ein köstlicher Schatz*. Zürich 1555. p. 289.

⁷⁾ M. Lescarbot, *Histoire de la Nouvelle-France*. 1612. Edit. Ed. Tross Paris 1866. pp. 805, 811, 820.

⁸⁾ Flückiger, *Dokumente zur Geschichte der Pharmazie*, p. 92.

⁹⁾ Deutsche Medizinisch-Zeitung 13 (1892), 45. No. 4.

¹⁰⁾ Report of Schimmel & Co. October 1894, 68 and April 1895, 29.

dren's hospital in Leipzig substantiate the claims made for a remarkable efficiency of the oil in the treatment of whooping cough.¹⁾

OIL OF JUNIPER BERRIES.

As *Oleum de granis Juniperi*, oil of juniper berries was kept in stock in the *Rathsapotheke* of Braunschweig in 1521²⁾. Its preparation is described by Valerius Cordus³⁾ in 1546.

The oil yield from the juniper berries was determined by Cartheuser⁴⁾ and Spielmann.⁵⁾

The oil distilled from juniper wood is mentioned repeatedly in the treatises on distillation. In the pharmacopœias and price ordinances of the 16. century it is mentioned together with the oil distilled from the fruit.⁶⁾

The juniper tar oil or cade oil, *Oleum Cadinum*, obtained by the process of destructive distillation is but rarely distilled from the wood of *Juniperus communis*, but mostly from *J. Oxycedrus*. It was known to the Romans.⁷⁾ Its method of preparation is described by Mesue the younger⁸⁾ who died in 1015.

¹⁾ O. Soltmann, *Keuchhusten und Cypressenöl*. Therapie der Gegenwart. March 1904.

²⁾ Flickiger, *Pharmakognosie*, 3rd ed., p. 898.

³⁾ Valerii Cordi *Dispensatorium Noricum*, p. 404.

⁴⁾ *Fundamenta materiæ medicæ* 1738. Vol. 2, p. 346.

⁵⁾ *Ibidem*. Vol. 2, p. 272.

⁶⁾ Saladini *Compendium aromatariorum*. 1488. *Index*. — H. Gualther. Ryff, *New gross Destillirbuch wohl gegründeter künstlicher Destillation*. Francof. 1556, fol. 181. — Val. Cordi *Dispensatorium Noricum*. 1546. — *Ein köstlicher Schatz Euonymi Philatri*. Editio 1555, pp. 228, 232, 306. — Van Helmont, *Ortus medicinarum vel opera et opuscula omnia*. Editio Lugdunensis 1648. *De lebribus*. Cap. IV, p. 33. Schnellenberg, *Artzneybuch*. Königsberg 1556. p. 35. — *Estimatio materiæ medicæ in usum publicum civitatum Marchiæ Brandenburgensis*. Autore Matthæo Flacco. Berolini 1574. Frankfurter Taxe. 1582.

⁷⁾ Dioscorides, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 102. — Plinii *Naturalis historia libri*. Cap. XXIV, 36. Editio Littré 1877. Vol. 1, p. 142. — Scribonius Largus, *Compositiæ medicamentorum*. Editio Helmreich 1887, pp. 47, 55, 56. — Joannes Actuarius, *De medicamentorum compositione*, J. Ruellio interprete. Basilicæ 1540, fol. 30. — Matthæus Platearius in *Circa instans*, in Choulant's *Handbuch der Bücherkunde für die ältere Medizin zur Kenntnis der griechischen, lateinischen und arabischen Schriften*. 2nd ed. Leipzig 1841. p. 299.

⁸⁾ Mesue, *Antidotarium seu Grabbadin medicamentorum libri XII*. Caput 12. *De oleis*. Comp. p. 24.

OIL OF SAVIN.

Savin was used medicinally and in veterinary practice by the Romans.¹⁾ It seems probable that the name *Sabina* has been derived from the mountainous country of the Sabines lying to the north-east of Rome. Dioscorides²⁾ and Pliny³⁾ mention the plant among those being used medicinally. Charlemagne in the ninth century mentioned it in his *Capitulare* and thus caused its cultivation in the northern Alps.⁴⁾ The abbess Hildegard of Bingen mentions savin as a remedy in her writings;⁵⁾ it is also one of the 77 remedies praised by Otto of Meudon (Macer Floridus).⁶⁾ In England the tree seems to have been cultivated and used before the Norman conquest.⁷⁾

During the period in which distilled waters were in general use, *Aqua sabinae* was also official and is enumerated in the treatises on distillation mentioned on pp. 39 *et seq.*

The distilled oil is first mentioned in the price ordinance of Frankfurt-on-the-Main for 1587 and was described by Joh. Begninus at the close of the seventeenth century.⁸⁾ Concerning the yield of the oil Friedrich Hoffmann seems to have made the first experiments about 1715.⁹⁾ G. W. Wedel examined the oil in 1707 according to the methods in vogue at his time.¹⁰⁾ The first chemical examination was made by Dumas in 1835.¹¹⁾

¹⁾ Marcus Porcius Cato, *De re rustica*, p. 70. — Editio Nisard, p. 25, Meyers *Geschichte der Botanik* Vol. I, p. 344.

²⁾ Pedanii Dioscoridis Anazarbei *De Materia medica libri quinque*. Editio Kfimi-Sprengel 1829, vol. I, p. 104.

³⁾ Plinii *Naturalis historiae libri*. Cap. XVII, 21 and cap. XXIV, 61. Editio Littré 1877, vol. I, p. 623 and vol. 2, p. 149.

⁴⁾ *Capitulare de villis et cortis imperialis*.

⁵⁾ Hildegardis Abbatissae *Subtilitatum diversarum naturalium creaturarum libri novem*. Editio Migne 1885, p. 1145.

⁶⁾ Macer Floridus, *De viribus herbarum una cum Walafridi Strabonis, Ottonis Crennonsensis et Joannis Folz carminibus similis argumenti*. Neapoli 1487. — Editio Choulant, Lipsiae 1832.

⁷⁾ Cockayne, *Leechdoms, wortcunning and Starcraft of early England*. 1865. Vol. 2, p. 12.

⁸⁾ Johannis Begnini *Tyracynum chymicum*, in Joh. Hartmannii *Opera omnia medico-chymica congesta atque pluribus aucta a Conrado Johrenio*. Francofurti ad Mœnum 1690. Vol. 3, p. 27.

⁹⁾ Fr. Hoffmannii *Opera omnia physico-medica*. Liber 65. *Observatio I. de oleis destillatis inque eorum distillatione observanda*.

¹⁰⁾ G. W. Wedel, *Dissertatio de Sabina*. Jenæ 1707.

¹¹⁾ Liebig's *Annalen* 15 (1835), 159.

LEBANON CEDAR OIL.

According to Herodotus and Diodor the Egyptians used cedar oil in the embalming of the dead. Pliny also mentions an *oleum cedrinum* and its use in the preservation of dead bodies.¹⁾ The method of preparation of this oil according to Herodotus, Dioscorides and Pliny will be found at the beginning of the next chapter. Whether this oil is that of the Lebanon cedar (*Cedrus Libani*, Barr.) can only be surmised, but not established with any degree of certainty.

On account of the durability of its wood, this tree is frequently mentioned in the old testament.²⁾

ANDROPOGON (CYMBOPOGON) OILS.

The aromatic grasses which at the present time yield a number of valuable volatile oils, such as palmarosa oil, ginger-grass oil, citronella oil, lemongrass oil and vetiver oil, have been used on account of their fragrance during antiquity: for the aromatization of wine; also of earthenware wine cups, the so-called Rhodian cups;³⁾ in the preparation of fragrant ointments⁴⁾ and oils; as incense in religious rites; and as couches during festivities. In Sanskrit writings, in the Old Testament,⁵⁾ and in other documents of antiquity, these grasses are referred to under

¹⁾ Herodotus II. 85. Diodor, lib I, 91. According to R. Sigismund, *Die Aromata*. Leipzig 1884. p. 5.

²⁾ In the books of the Old Testament coniferous woods are frequently referred to. The names used in the translations presumably do not always indicate the proper source of these words. Wherever the words cedar and pine are used, Lebanon cedar probably is meant. Such references are: Leviticus, 14:4. — 1. Kings, 4:33; 5:6, 8 and 10; 6:9, 15, 18, 20 and 26; 7:2, 3, 7, 12 and 14; 10:27. 2. Chronicles, 2:8; 3:5 and 9. Isaiah, 14:8; 37:24, 60 and 61. Hesiakiah, 27:2. — 2. Samuel, 6:5. Zechariah, 11:1 and 2. Revelations, 18:12.

³⁾ Athenæi Naucratis: *Deipnosophistarum*. Lib. XV, p. 472. Plinii *Naturalis historiae libri*. Lib. V, pp. 64, 65 and lib. XIV, p. 15. Horatii *Carmen*. XII, 16 17:

"Nardo vina merebere

Nardi parvus onyx eliciet cadum"

⁴⁾ Dioscorides, *De materia medica libri quinque*. Lib. I, p. 52. — Plinii *Naturalis historiae libri*. Lib. XIII, p. 2.

⁵⁾ Exodus, 30:34. Song of Solomon, 4:13 and 14.

various names. The names used in the translations of the Bible and other ancient writings for spices and anointing oils¹⁾ such as *narde*, *stakte*, *schōnos*, etc., apparently have also been used synonymously for the fragrant andropogon grasses and their roots. Of these, it may be supposed that *Andropogon laniger*, Desf. was the best known and most used during antiquity, inasmuch as it was more widely distributed throughout northern India, Thibet, Persia and Arabia as far as Egypt, Nubia and Ethiopia than the other species. Originally,²⁾ however, and again in more modern times, the term *narde* was applied only to the aromatic root of the valerianaceous *Nardostachys jatamansi*, D. C., indigenous to the Himalayas of northern India, perhaps also to *Valeriana celtica*, L. indigenous to the European Alps.

The Greek and Roman writers possibly referred to the same aromatic andropogon species when they used the words *ξίανος* or *αζιανός*, also *juncus*.³⁾ In the occident they apparently have never been cultivated nor introduced in the dried condition.

The first mention of andropogon grasses⁴⁾ by European travelers is to be found in the works of Garcia da Orta,⁵⁾ van Rheede tot Draakenstein,⁶⁾ — who was governor of the Dutch East-India company on the Malabar coast about the middle of the seventeenth century, — and of G. E. Rumpf⁷⁾ (Rumphius, also Plinius indicus), Dutch governor in Amboyna during the second half of the seventeenth century. The first sample of a distilled andropogon oil, a lemon-grass oil, is said to have been

¹⁾ Wilhelm Nowack, *Lehrbuch der hebräischen Archäologie*. Freiburg 1894. Vol. I, p. 133.

²⁾ Dioscorides, *De materia medica libri quinque*. Lib. I, 6 and 77.

³⁾ Dioscorides, *De materia medica libri quinque*. Lib. I, pp. 2, 16, 17. Editio Kühn-Sprengel 1829. Vol. I, p. 30. — Plinii *Naturalis historiae libri*. Lib. XII, pp. 26, 59, 62 and lib. XIII, p. 2.

⁴⁾ A detailed account of the individual grasses is given by Otto Stapf. *The Oil-Grasses of India and Ceylon*. Bulletin of Miscellaneous Information Royal Botanic Gardens, Kew. 1906. No. 8, p. 297.

⁵⁾ Garcias ab Horto, *Colloquios dos simples e drogas he cousas medicinaes da India, e assi dalguas frutas achadas nella onde se tratam*. 1563.

⁶⁾ Van Rheede, *Hortus indicus malabaricus*. Amstelodami 1678-1703.

⁷⁾ Rumphius, *Herbarium amboinense*. Amstelodami 1741-1755.

brought to Europe from the Moluccas in 1717.¹⁾ However, the distillation of these oils on a large scale and their introduction into the commerce of the world and into industry apparently first began in 1820. In this year the botanist William Roxburgh, who was Director of the Botanical Garden at Calcutta for a long time, mentions lemon-grass oil as coming from the Moluccas.²⁾ In 1832 the first large assignment was received in London. Since then, it, as well as the palmarosa oil and somewhat later citronella oil, have been finding increased application in perfumery and especially in the soap industry. As a result of the ever increasing demand, the cultivation of these aromatic grasses, has increased considerably especially that of the citronella grasses in Ceylon, and during the last decade of the 19. century also in Java, so that these oils are now exported in large quantities.

CALAMUS OIL.

Both as spice and as medicament, calamus root is mentioned in the writings of antiquity. Thus it is mentioned in the *Ayur-Vedas*,³⁾ in the Old Testament⁴⁾ and in other of the earliest written documents. In the scientific treatises of the Greeks and Romans⁵⁾ it is likewise recorded. During the middle ages a distinction between Asiatic and European calamus was maintained. Still later a distinction was made between the commercial varieties from the several countries from which it was obtained. As one of the spices introduced into Portugal from India,

¹⁾ *Ephemerides naturæ curiosorum*. 5—6 cent. London (1717). Appendix p. 157. — Medical and Physical Transactions. London. Vol. I (1825), p. 367 und Vol. 3 (1827), p. 231.

²⁾ Roxburgh, *Flora indica*, edited by Carey and Wallich. 1820—1824. Calcutta. Vol. I, p. 280.

³⁾ Page 16, footnote 1. — Royle, *Essay on the antiquity of Hindoo Medicine*. London 1837. p. 28 and 34.

⁴⁾ Exodus, 30:23. — Isaiah, 43:24. — Heseekiah, 27:19. — Song of Solomon, 4:14.

⁵⁾ Agatharchides, *De mari Erythræo*, p. 97. — Theophrasti *Historia plantarum* Lib. 9. 7. — Dioscorides, *De materia medica*. Lib. 1. 17 and 52. Editio Kühn-Sprengel, p. 11. — Plinii *Naturalis historiæ libri*. Lib. XII. 12, 48. Lib. XXV. 100. — Plutarchi *Moralia*. *Isis et Osiris*. — Strabonis, *Geographia* XVI. 4.

Odoardo Barbosa¹⁾ mentions calamus in 1511. Matthias Lobelius of Flanders,²⁾ in the second half of the 16. century, claims that the calamus imported into Antwerp via Venice is better than that imported from Siebenbuergen and Russia. Rheede supplied the first good illustration of the plant.³⁾

Calamus is reported to have been cultivated in the thirteenth century in Poland;⁴⁾ in Germany first during the sixteenth century;⁵⁾ whence it became more widely distributed.⁶⁾ Calamus is also indigenous to North America, being found from Nova Scotia south to Florida and westward to Minnesota, Iowa and Kansas. Of botanists Schöpf first observed it in 1783 in Pennsylvania and New Jersey.⁷⁾

The distilled oil of calamus is first mentioned in the price ordinance of Frankfurt of 1582 and in the Dispensatorium Noricum of 1589. The yield of oil obtainable upon distillation of the rhizome was determined at the beginning of the eighteenth century by Fr. Hoffmann⁸⁾ and Caspar Neumann;⁹⁾ and about the middle of the eighteenth century by Joh. Fr. Cartheuser.¹⁰⁾ The first investigations of the oil appear to have been made by

¹⁾ Ramusio, *Della navigation et viaggi.* Venetia 1554. fol. 413-417. Flückiger, *Dokumente zur Geschichte der Pharmazie.* 1876. p. 15.

²⁾ Mathias de Lohel et Petri Pena: *Nova stirpium adversaria.* London 1576. p. 29.

³⁾ *Hortus indicus malabaricus.* Amstelodamo. 1678-1703. Vol. XI. (1692), Tab. 48 and 49.

⁴⁾ Rostafinski, *Flora Polonica Prodrromus* 1873. p. 12. Clusius, *Rariorum plantarum historia.* Antwerpiae 1601. fol. 230 and 232.

⁵⁾ Bock, *Teutsche Speiskammer.* Strassburg 1550. p. 104. — Matthioli *Commentarii in Dioscoridem.* 1544. Editio 1565, p. 20. Joach. Camerarius, *Hortus medicus et philosophicus.* Francofurti 1588. p. 5.

⁶⁾ The assumption that calamus was spread since 1574 from Vienna through botanical gardens as a result of the efforts of Charles de l'Escluse (Clusius) who lived in Vienna from 1573-1588 (Luertzen, *Handbuch der systematischen Botanik*, vol. 2, p. 320) can scarcely be accepted as a full explanation of its wide distribution. (Engler und Prantl, *Natürliche Pflanzenfamilien.* T. II. Abt. III. p. 118.)

⁷⁾ Schöpf, *Materna medica americana.* Erlanga: 1787.

⁸⁾ Fr. Hoffmannii *Opera omnia physico-medica.* 1740. Liber 65. *Observatio I.: De oleis destillatis atque eorum destillatione observanda.* p. 8.

⁹⁾ Casp. Neumann, *Chymia medica dogmatico-experimentalis.* Editio Kessel. 1749. Vol. 2, p. 272.

¹⁰⁾ See p. 71, footnote 2.

Joh. Ad. Wedel¹⁾ in 1718 and by Joh. Barth. Trommsdorff in 1808.²⁾ Later examinations are by Martius³⁾ in 1832, Schnedermann⁴⁾ in 1842, J. H. Gladstone⁵⁾ in 1863, and A. Kurbatow⁶⁾ in 1873.

SAFFRON OIL.

In the literature of antiquity saffron is frequently mentioned among the spices, also as medicament and dyestuff.⁷⁾ During the Arabian period it was cultivated, especially in Persia⁸⁾ and Spain.⁹⁾ Its introduction into western Europe as far as England was no doubt assisted by the crusades.¹⁰⁾ In the commerce with the Levante, saffron was one of the most costly spices and played an important role. As an object subjected to heavy duties, it frequently became the subject of rigid legislation,¹¹⁾ also

¹⁾ Joh. Adolf Wedel, *De Cakamo aromatico*. Dissertatio. Jenæ 1718.

²⁾ Trommsdorff's Journal der Pharmazie 1^o, II. (1809), 122.

³⁾ Liebig's Annalen 4 (1832), 264 and 266.

⁴⁾ *Ibidem* 41 (1842), 374.

⁵⁾ Journ. chem. Soc. 17 (1864), 1., Rel. Jahresber. d. Chem. 1863, 546 and 547.

⁶⁾ Liebig's Annalen 174 (1874), 4.

⁷⁾ Song of Solomon, 4: 14. - Homeri Ilias, 14, 348. Dioscorides, *De Materia medica libri quinque*. Editio Kühn-Sprengel. Vol. 1, 39. - Plinii *Naturalis historiae libri*. Lib. XXI, 17 and 18. - Virgilii *Georgica* Lib. IV, 109. Alex. Tralliani *medici libri duodecim, graece et latine*. Basilæ 1556. German edition by Th. Puschmann. Vienna 1878. Matthæus Platearius, *Circa instans* in Choulant's *Handbuch der Bücherkunde für die ältere Medizin zur Kenntnis der griechischen, lateinischen und arabischen Schriften*. 2nd ed. Leipzig 1841. p. 299. - Hehn, *Kulturpflanzen und Haustiere in ihrem Übergange aus Asien nach Griechenland und Italien*. 3rd ed. 1877. pp. 225-231. *Liber pontificalis*. Editio Duchesne. Paris 1886. Vol. 1, p. 177.

⁸⁾ Istachri, *Buch der Länder*. German translation by Mordtmann. pp. 87, 93, 124 and 126. Edrisi, *Géographie, traduite par Amédée Jaubert*. 1836. pp. 168 and 192. - Meyer, *Geschichte der Botanik*. Vol. 3, pp. 282, 284, 299. - Bretschneider, *Chinese Botanical Works*. Foochow 1870. p. 15. Ibn Baïar, *Traité des Simples*. Edit. Leclerc. 1881. Vol. 2, p. 209.

⁹⁾ *Le Calendrier de Cordoue de l'année 961*. Leyde 1873. pp. 33, 109.

¹⁰⁾ Conrad et Waldmann, *Traité du Safran du Gâtinais*. Paris 1846. p. 20. - Morant, *History and Antiquities of Essex*. 1768. Vol. 2, p. 545. - *Revue pharmaceutique*. 1858. p. 58. - Douglass, *Philosophical Transactions*. November 1728. p. 566.

¹¹⁾ Simonsfeld, *Der Fondaco dei Tedeschi in Venedig und die deutsch-venetianischen Handelsbeziehungen*. Stuttgart 1887. p. 35. - Mone, *Zeit-*

because it was excessively adulterated with the florets of *Carthamus tinctorius* and parts of other plants. So important did the commerce in saffron become during the middle ages that the traders in spices of some of the larger German cities united under the name of *Safranzünfte* to special corporations.¹⁾

Into the United States of North America, saffron appears to have been introduced by German immigrants during the first half of the 18. century. In 1748 Peter Kalm found saffron gardens near Philadelphia and in New Jersey,²⁾ and in 1787 Joh. David Schöepf found them near Lancaster, Pa.³⁾

The distilled oil of saffron is first mentioned by Walter Ryff⁴⁾ and Conrad Gesner,⁵⁾ and is enumerated in the municipal price ordinance of Nürnberg of 1613. The older medical treatises do not mention it. The yield was apparently first determined in 1670.⁶⁾ Saffron and its constituents were further examined by Bouillon Lagrange and Vogel in 1810.⁷⁾ In 1821 Henry examined the coloring matter of saffron and arrived at the conclusion that the yield of oil was almost doubled if for every ounce of saffron 8 oz. of common salt and 4 oz. of potassa are added to the water in the still.⁸⁾

schrift für die Geschichte des Oberrheins 5 (1854), 28. — Warnkönig, *Histoire de la Flandre*. Vol. 4 (1851), p. 449. — Flückiger, Schweiz. Wochenschr. 1. Chem. u. Pharm. 19 (1881), 109. — Falke, *Geschichte des deutschen Handels*. 1859. Vol. 1, p. 267. — Elhen, *Zur Lehre von der Warenfälschung*. Dissertation. Tübingen 1881. p. 37. Flückiger, *Beiträge zur älteren Geschichte der Pharmazie in Bern*. 1862. p. 6. — Roth, *Geschichte des Nürnbergschen Handels*. 1802. Vol. 4, p. 221. — Beckmann, *Beiträge zur Geschichte der Erfindungen*. 1784. Vol. 2, pp. 88 and 91. — Peters, *Ans pharmazeutischer Vorzeit*. 1899. Vol. 2, pp. 225—229.

¹⁾ Flückiger, *Dokumente zur Geschichte der Pharmazie*. 1876. pp. 46 and 66.

²⁾ Prof. Peter Kalm's *Reise nach dem nördlichen Nordamerika im Jahre 1748—1749*. Göttingen 1754. Vol. 3, p. 135.

³⁾ Joh. David Schöepf, *Materia medica Americana potissimum regni vegetabilis*. Erlangæ 1787.

⁴⁾ Gualtherus Ryff, *New gross Destillirbuch*. 1556. fol. 188.

⁵⁾ Euonymus Philatrius, *Ein köstlicher Schatz*. Zürich 1555. fol. 222.

⁶⁾ Joh. Ferd. Hertodt, *Crocologia*. Dissertation. Jenæ 1671.

⁷⁾ Annales de Chimie 80 (1811), 185. Trommsdorff's Journ. der Pharm. 21, 1. (1812), 206.

⁸⁾ Trommsdorff's Neues Journ. der Pharm. 6 (1822), 65. — Berliner Jahrbuch 1. Pharm. 24, 1. (1822), 160.

OIL OF ZEDOARY.

During the 6. and 7. centuries, zedoary is mentioned by Aetius, Paulus Aegineta and other writers as coming from India where it had been in use for a long time. In western Europe it became known toward the beginning of the 8. century.¹⁾ From that time on, zedoary is frequently referred to, under various names,²⁾ among the spices,³⁾ in the formulas of pharmacopœias,⁴⁾ and by travellers.

During the middle ages zedoary appears to have been introduced into commerce principally from the Malabar coast.⁵⁾

The distilled oil of zedoary is first mentioned in the price ordinance of Berlin of 1574,⁶⁾ in those of Worms and Frankfurt-on-the-Main of 1582, also in the *Dispensatorium Noricum* of 1589. Examinations as to yield and properties of the oil were later made by Neumann⁷⁾ (1785), Dehne⁸⁾ (1779) and E. F. Geoffroy⁹⁾ (1757).

OIL OF GALANGAL.

Galangal appears to have been used in China during antiquity. It is mentioned in the *Ayur-Vedas* of Susruta,¹⁰⁾ also by Plutarch.¹¹⁾ The Arabian physicians used it for medicinal

¹⁾ Niccolò de Conti. In Kunstmann's *Kenntnis Indiens im 15. Jahrhundert*. Munich 1863. p. 48. — Odoardo Barbosa, *Delle navigazioni et viaggi*. Venetia 1554. pp. 413 and 417. — Meyer, *Geschichte der Botanik*. Vol. 2, p. 421.

²⁾ Zitar. Zodear. Zitewar. Citowart. Citoal. Cytoal. Zerumbet.

³⁾ Guérard, *Polyptique de l'abbé Irminon II, Statuta antiqua abbatiae St. Petri Corbeinensis*. Paris 1844. — W. Heyd, *Geschichte des Levantehandels*. 1879. Vol. 1, p. 104.

⁴⁾ I. G. Eckhart, *Commentarii de rebus Franciæ orientalis et episcopatus Wirceburgensis*. Wirceburgi 1729. Tom. II, p. 980. — F. A. Reuss, *Walafriedi Strahi Hortulus*. Wirceburgi 1834. p. 73.

⁵⁾ Kunstmann's *Kenntnis Indiens im 15. Jahrhundert*. 1863. p. 48. — Flückiger, *Dokumente zur Geschichte der Pharmazie*. 1876. p. 15.

⁶⁾ *Estimatio materiæ medicæ . . . in gratiam et usum publicum civitatum Marchiæ Brandenburgensis*. Autore Matthæo Flacco. Berolini 1574.

⁷⁾ J. F. A. Götting's *Almanach für Scheidekünstler* 1785, 118.

⁸⁾ Lorenz Crell's *Chemisches Journal* 3 (1779), 20.

⁹⁾ E. F. Geoffroy, *Tractatus de materia medica*. Paris 1757. Vol. 3, p. 265.

¹⁰⁾ See p. 16, footnote 1.

¹¹⁾ Plutarchi *Moralia. Isis et Osiris*. The use of galangal for fumigating purposes by the ancient Egyptians is referred to.

purposes and thus, no doubt, assisted in its introduction into western Europe. Thus Rhazes, Avicenna, Alkindi¹⁾ and other physicians who lived during the 9. and 10. centuries, mention galangal in their writings as an esteemed remedy. Its importation is reported in the 9. century by the Arabian geographer Ibn Kurdadbeh,²⁾ and in the beginning of the 12. century by the Sicilian geographer Edrisi.³⁾ In the *Della decima* etc., a commercial treatise of the first half of the 14. century by the Florentine merchant Pegolotti, galangal is described as occurring in two varieties, viz., the light and the heavy.⁴⁾ Marco Polo reports on the cultivation of the plant in China and Java.⁵⁾ In 1563 Garcia da Orta, a physician in Goa, describes two varieties of galangal, a smaller variety coming from China, and a larger one from Java.⁶⁾ The first good illustration was published by Rumpf in 1754.⁷⁾

In German literature the rhizome is found as early as the 8. century and is mentioned as a medicinal drug. Galangal also occurs as one of the ingredients of a prescription found in a medical manuscript of the 8. century in the library of the University of Würzburg.⁸⁾ It is also mentioned in a formulary of

¹⁾ Macer Floridus, *De virtutibus herbarum*. Naples 1487. Editio Choulant. 1832. Cap. 70. Ibn Baitar, *Traité des Simples*. Editio Leclerc. Vol. 2, p. 61.

²⁾ *Le livre des routes et des provinces*, par Ibn Khordadbeh, traduite par B. de Meynard; en *Journal asiatique*, Ser. VI, Tom. 5 (1865), p. 294.

³⁾ *Géographie d'Idrisi*, traduite par A. Jaubert. 1836. Tom. 1, p. 51.

⁴⁾ Francesco Balducci Pegolotti, *La pratica della mercatura scritta*. In Pagnini's *Della decima e delle altre gravanze, della moneta* etc. Lishoa e Lucca. 1766. pp. 296 and 375.

⁵⁾ Panthier, *Le livre de Marco Polo*. 1865. pp. 522 and 561.

⁶⁾ Garcia ab Horto, *Colloquios dos simples e drogas he cousas medicinas da India*. Goa 1563. *Colloquio* 24. Whereas at the present time only the smaller root, the *Radix galangæ minoris* obtained from *Alpinia officinarum*, Hance is in use and obtainable commercially the *Radix galangæ majores* obtained from *Alpinia Galanga*, Willd. was formerly also current. The latter came from Java. See also Daniel Hanbury, *Science papers*. 1876. p. 370.

⁷⁾ G. E. Rumphius, *Herbarium amboinense* etc. Amstelodami 1741. 1754. Vol. 5, Tab. 63.

⁸⁾ *Würzburger Universitätsbibliothek Manuscriptes* Mp. th. fol. 146. — Printed in I. A. Reuss, *Walatridi Strahi Hortulus*. Wirceburgi 1834. p. 37. D. G. ab Eckhart, *Commentarii de rebus Franciæ orientalis et episcopatus Wirceburgensis*. Wirceburgi 1729. Vol. 2, p. 980, *Glossæ Theotiscæ*.

the 9. century by Bishop Salomo III of Constance.¹⁾ Its medicinal virtues are praised by Matthæus Platearius,²⁾ a Salernitan scientist of the 12. century, and by Hildegard,³⁾ abbess of Bingen.

Galangal found a place in the *Dispensatorium Noricum*, but its volatile oil appears to have been distilled later. It is first mentioned in the municipal price ordinance of Frankfurt-on-the-Main in 1587.

OIL OF GINGER.

Ginger appears to have been used as a spice by the Chinese and the Indians. It is mentioned repeatedly in Chinese medical treatises, in the *Ayur-Vedas* of Susruta, also in Sanscrit literature and later in the Talmud. The Greeks and Romans⁴⁾ obtained ginger via the Red Sea and hence regarded Arabia as its geographic source. In the 3. century, however, it was counted among the Indian products brought via the Red Sea and Alexandria.⁵⁾ Ginger was one of the favorite spices of the Romans.⁶⁾ Apparently it was introduced into Germany⁷⁾ and France⁸⁾ during the 9. century and into England⁹⁾ during the 10. century. A better understanding

¹⁾ Dümmler, *Formelbuch des Bischofs Salomo von Konstanz*. In *St. Gallische Denkmäler aus der Karolingischen Zeit*. Zürich 1859. p. 37.

²⁾ Circa instans. *Liber de simplicibus medicinis*. In Choulant's *Handbuch der Bücherkunde für die ältere Medicin*. 2nd ed. Leipzig 1841. p. 229.

³⁾ Hildegardis Abbatissæ *Subtilitatum diversarum naturarum creaturarum libri novem*. In Migne, *Patrologiæ Cursus completus*. Tom. 197. *Infantia Patistorum*. 1855. pp. 1134 and 1158.

⁴⁾ Dioscorides, *De Materia medica libri quinque*. 1st editio Kühn-Sprengel. 1829. Vol. 2, p. 300.

⁵⁾ Vincent, *Commerce and Navigation of the Ancients in the Indian Ocean*. 1807. Vol. 2, p. 695. Meyer, *Geschichte der Botanik*. Vol. 2, p. 167.

⁶⁾ Apicius Caelius, *De re coquinaria libri decem*. Editio Schuch. Heidelberg 1867. pp. 36, 45, 68, 98, 105, 138, 139, 142, 165.

⁷⁾ Cless, *Landes- und Kulturgeschichte von Württemberg*. 1807. Vol. 2, p. 260. In the preface of a Codex of the 8. century of the Würzburg Library (Mp. th. f. 146) it is mentioned together with cinnamon, costus, cloves, pepper and gentian. The title of this manuscript is J. G. ab Eckhardt, *Commentarii de rebus Franciæ orientalis et episcopatus Wirceburgensis, Glossæ Theotiscæ*. The preface referred to is printed in F. A. Reuss, *Walafriedi Strahi Hortulus*. Wirceburgi 1834. p. 73.

⁸⁾ W. Heydt, *Levantehandel im Mittelalter*. 1879. Vol. 1, p. 103, footnote 3.

⁹⁾ *Pharmacographia*. p. 635. - Rogers, *History of Agriculture and Prices in England*. 1866. Vol. 1, p. 629.

as to the geographical source of ginger was obtained by Marco Polo, Pegolotti, Barbosa and Niccolo Conti on their voyages along the coast and among the islands of southwestern Asia.⁴⁾ As early as the 13. century ginger entered the market either fresh (*zenzeri verdi*), preserved with sugar (*giengiario confetto*) or dried. For a long time Alexandria was the principal port for the purchase of this delicacy.⁵⁾

As a dutiable article of commerce, ginger is mentioned repeatedly: thus, in 1173 in Acre in Palestine,⁶⁾ in 1221 in Barcelona,⁷⁾ in 1228 in Marseilles,⁸⁾ and in 1296 in Paris.⁹⁾ In an old apocryphal German pharmacopœia of the 12. century, ginger occurs in several formulas.¹⁰⁾

Into the West Indies and Mexico, the ginger plant was introduced by the Spaniards during the middle of the 16. century;¹¹⁾ and as early as 1547 ginger was exported from Jamaica¹²⁾ to Spain, in 1585 from St. Domingo and in 1654 from Barbadoes.¹³⁾

The first mention of a distilled oil of ginger is found in a municipal spice ordinance of Copenhagen of the year 1672. The yield was determined in the course of the 18. century first by

⁴⁾ *Le livre de Marco Polo, publié par Pauthier.* 1865. Vol. 2, pp. 381, 488. — Pegolotti, in Pagnini's *Della decima e delle altre gravetze, della moneta e della mesatura de' Fiorentini lino al secolo XVI.* Lisboa e Lucca 1766, p. 360. — Od. Barbosa. Editio Ramusio, *Delle navigationi et viaggi.* Venetiae 1554. pp. 311 and 323. — Niccolò Conti, *India in the 15. century.* Edition Major, London 1857. — Kunstmann, *Kenntnis Indiens im 15. Jahrhundert.* Munich 1863.

⁵⁾ Pegolotti, Editio Pagnini. *Della decima etc.* pp. 298 and 317.

⁶⁾ *Recueil des Historiens des Croisades.* Lois 1843. Tom. 2, p. 176.

⁷⁾ Capmany, *Memorias historicas sobre la Marina Comercio y Artes de la Ciudad de Barcelona.* Madrid 1779. Vol. 2, p. 3.

⁸⁾ Méry et Gundon, *Histoire des Actes de la Municipalité de Marseille.* 1841. Tom. 1, p. 372.

⁹⁾ *Revue archéologique.* Paris 1852. Tom. 9, p. 213.

¹⁰⁾ Pfeiffer, *Zwei deutsche Arzneihücher aus dem 12. und 13. Jahrhundert, in Sitzungsberichte der Wiener Akademie d. Wissenschaften* 42 (1863), 124, 138, 159. — Haeser, *Geschichte der Medicin.* 1875. Vol. 1, p. 663.

¹¹⁾ Monardes, *Historia medicinal de las cosas que se traen de nuestras Indias occidentales que sirven en medicina.* Sevilla 1574. p. 99. — Editio Clusius. Antverpiæ 1593. p. 309.

¹²⁾ Renny, *History of Jamaica.* London 1807. p. 154.

¹³⁾ *Calendar of State Papers. Colonial series 1574—1660.* London 1860. p. 4.

Caspar Neumann,⁴⁾ and then by J. A. Gesner,⁵⁾ E. F. Geoffroy⁶⁾ and Friedrich Cartheuser.⁴⁾

The first illustration of *Zingiber officinale*, Roscoe was published by H. A. van Rheede in 1670.⁵⁾

OIL OF CARDAMOM.

Cardamom, i. e. the capsular fruit of several species of *Elettaria* and *Ammomum*, (N. O. *Zingiberaceæ*), indigenous in the islands of the East Indian archipelago, appears, to have been used during antiquity. In the *Ayur-Vedas* of Susruta⁷⁾ they are mentioned as *Ela*. According to Plutarch⁸⁾ the Egyptians used cardamom together with other spices in religious incense.

Later writers use as synonyms the terms *Amomis*, *Amomum* and *Cardamomum*.⁹⁾ Although a number of spices were imported during antiquity from southern India, it is highly probable that these designations were applied only to cardamom. Dioscorides,¹⁰⁾ Theophrastus,¹¹⁾ Pliny,¹²⁾ Scribonius Largus and Alex. Trallianus,¹³⁾ mention cardamom as well as Amom, mostly together with pepper, cloves and nutmeg. During the 3. and 4. centuries, when Roman luxury had reached its climax, cardamom was one of the favorite

¹⁾ *Chymia medica dogmatico-experimentalis*. Editio Kessel. 1749. Vol. 2, p. 638.

²⁾ Joh. Alh. Gesneri *Dissertatio de Zingibere*. Altdorf 1723. p. 18.

³⁾ *Tractatus de materia medica*. Paris 1757. Vol. 2, p. 265.

⁴⁾ *Elementa Chymie dogmatico-experimentalis una cum synopsi Materiae medicae selectioris*. Halæ 1736. Vol. 2, p. 62.

⁵⁾ *Hortus indicus malabaricus*. Amstelodami 1678-1703. Vol. 2, p. 24, Tab. 12.

⁶⁾ See p. 16, footnote 1.

⁷⁾ Plutarchi *Moralia*. *Isis et Osiris*.

⁸⁾ The usage of these synonyms continued up to the close of the 18. century. Thus in Murray's *Apparatus Medicamentorum* (Göttingen 1790) and in similar works the designation *Amomum*, *Cardamomum* still occurs.

⁹⁾ Dioscorides, *De materia medica libri quinque*. Editio Kühn-Sprengel. Leipzig 1829. Vol. 1, p. 14.

¹⁰⁾ Theophrasti *Eresii opera, quæ supersunt omnia*. *Historia plantarum*. Editio Wimmer. Parisiis 1866. p. 147.

¹¹⁾ Plinii *Naturalis historiae libri*. Lib. XII. 28, 29. — Editio Littré. Paris 1877. Vol. 1, pp. 482, 483.

¹²⁾ Alexandri Tralliani *medici libri XII*. Basilæ 1556. Editio Puschmann. 1878. Vol. 2, p. 354.

spices.¹⁾ As products of farther India, the Arabian traveler Masudi²⁾ in 912 mentions cardamom, cubebs, nutmegs, cloves, camphor, sandelwood and linaloes. In the middle of the 12. century, the Sicilian geographer Edrisi³⁾ makes a distinction between Ceylon and Chinese cardamom. Like Barbosa⁴⁾ and Pegolotti,⁵⁾ he also mentions that at that time the spices entered the European market via Aden and Alexandria, also via Accon⁶⁾ during the existence of the Kingdom of Jerusalem.

Even at that time, a distinction was made between wild and cultivated cardamom.⁷⁾ Garcia da Orta⁸⁾ distinguished between a larger but less aromatic cardamom from Ceylon and a smaller but more spicy variety. Finally, at the time of Valerius Cordus the Malabar *Cardamomum minus* was given preference over the larger kind.⁹⁾

The first good illustration of *Elettaria cardamomum* was published by Henry van Rheede,¹⁰⁾ governor of the Dutch East

¹⁾ Apicius Caelius, *De re coquinaria libri X.* Editio Schuch. Heidelberg 1867. pp. 36, 45, 64, 98, 105, 139, 142, 165. — Hieronymi *Opera omnia.* Editio Migne *Patrologiae cursus completus.* Vol. 2, p. 297.

²⁾ Ali el-Masudi, *Praeres d'Or.* Editio Meynard et Courteille. Paris 1861-1877. Vol. 1, p. 341.

³⁾ *Géographie d'Edrisi, traduite par Amédée Jaubert.* 1836-1840. Vol. 1, pp. 51, 341.

⁴⁾ Libro di Odoardo Barbosa. In Ramusio's *Delle navigationi et viaggi.* Venetia 1554. fol. 413-417. Editio Hakluyt Society in London: Description of the Coasts of East Africa and Malabar. 1886. pp. 59, 64, 147, 154.

⁵⁾ Francesco Balducci Pegolotti, *La pratica della mercatura.* In Pagnini's *Della decima e delle altre gravanze, della moneta e della mercatura de' Fiorentini fino al secolo XIV.* Livorno e Lucca 1766. p. 57.

⁶⁾ Beugnot, *Asses de Jérusalem.* Paris. Vol. 2, p. 175.

⁷⁾ Pegolotti, *Cardamomi salvatici, domestici.* l. c. (see footnote 5) p. 211 and 296.

⁸⁾ Garcias ah Horto, *Colloquios dos simples e drogas he cousas medicinaes da India, e assai dalguas frutas achadas nella onde se tratam.* 1563. Edited by Carolus Clusius in 1567 with the title: *Aromaticum et Simplicium aliquot medicamentorum apud Indus nascentium historia. primum quidem Lusitanica lingua dicitur conscripta,* a D. Garcia ah Horto, Proregis Indiae Medico: *Deinde Latino illustrata* a Carolo Clusio Atrebate. Antverpiae p. 98. The original Portuguese was reprinted in 1872 by F. A. von Varnhagen. See p. 51 of this edition.

⁹⁾ Valerius Cordus, *Dispensatorium Noricum.* Editio Paris. pp. 40, 76, 77, 115, 157, 158.

¹⁰⁾ Van Rheede, *Hortus indicus malabaricus, cum notis et commentariis Johanni Commelini.* Amstelodami 1678-1703. Vol. XI (1692), Tab. 4-5: *Elettari.*

India Company on the Malabar coast, and by Georg Eberhard Rumpf,¹⁾ who, born in Hanau, lived as merchant and botanist in Amboina.

Cardamom oil was distilled as early as 1540 by Valerius Cordus.²⁾ The yield was determined by Caspar Neumann,³⁾ C. Ph. Martius,⁴⁾ Joh. Friedr. Cartheuser and J. R. Spielmann.⁵⁾

OIL OF PARADISE GRAINS.

The Grains of Paradise were formerly used extensively as a spice. In the apothecary shops they were known as *Grana Paradisi*, *Semina Cardamomi majoris*, and as *Piper Melegueta*.

Oil of paradise grains was distilled by Porta⁶⁾ at the beginning of the 17. century and used medicinally.

OIL OF PEPPER.

Pepper is one of the oldest known spices mentioned in Sanskrit and ancient Indian literature. In the 4. century B. C. it is mentioned by Theophrastus,⁷⁾ Dioscorides,⁸⁾ and Pliny⁹⁾ already distinguished between black, white and long pepper and counted the first among the most important spices of their time. Toward the end of the 1. century, we already find special warehouses (*horrea piperataria*) for this precious ware. As ports of exports for pepper, places on the west Indian coast, between

¹⁾ Rumphius, *Herbarium Amboinense (Het Amboinische Kruidboek)*. Editio Johanni Burmanni. Amstelod. 1741—1755. Vol. 3, p. 152 also plate 65. *Amomum Cardamomum*. (This work had been completed by Georg Eberhard Rumpf in 1690, but was not published until after his death viz. in 1741.)

²⁾ Valer. Cordus, *De artificiosis extractionibus*. 1561. fol. 226.

³⁾ Caspar Neumann, *Chymia medica dogmatico-experimentalis*. Editio Kessel. 1749. Vol. 1, p. 328.

⁴⁾ J. C. S. Schweigger's *Journal für Chemie u. Physik* 3 (1811), 311.

⁵⁾ Jacob R. Spielmann, *Cardamomi historia et vindicia*. Argentor. 1762.

⁶⁾ Porta, *De destillatione*. Romæ 1608. Lib. IV. Cap. 4.

⁷⁾ Theophrasti Eresii *opera quæ supersunt omnia*. IX. 20. — Editio Wimmer. Vol. 1, p. 162; vol. 2, p. 476.

⁸⁾ Dioscorides, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 298.

⁹⁾ Plinii *Naturalis historia libri*. Lib. XII, 14. — Editio Littré. Vol. 1, p. 478.

Mangalose and Cochin, are enumerated in the *Periplus* of the Erythrean sea, a commercial catalogue that was presumably written in A. D. 76, in Alexandria.¹⁾

Into western Europe pepper was likewise introduced at an early date. The quantities in which it was imported, in spite of its high price at the beginning of the 5. century, become apparent from the statement that the west Roman Emperor, Honorius paid a tribute of 3000 lbs. pepper to Alaric, King of the Visigoths in 408, while the latter was besieging Rome.²⁾ Pepper retained its high price late into the middle ages. Hence, it was used in place of the noble metals in the payment of tribute, taxes, rent, duty and ransom; as gifts and as objects of bequest.³⁾ Among the presents made to the popes by the East and West Roman emperors, pepper is usually enumerated first among the costly spices. According to a privilege granted 716 by the Merovingian king, Chilperich II, the monastery at Corbie in southern France obtained among other objects pepper, cloves, cinnamon and spike as annual revenue.⁴⁾ Boniface, the apostle of the Germans, repeatedly obtained from Roman prelates,⁵⁾ presents of aromatics for incense purposes, among which pepper is enumerated.

In 1290 Marco Polo found pepper in abundance in the islands of the Malay Archipelago and on the Indian coast. It constituted an important article of commerce with China.⁶⁾

The increasing demand for pepper and the high price paid therefor constituted not the least of the motives for the search of an all water route to the East Indies. This was accomplished

¹⁾ Iabricius, *Der Periplus des Erythräischen Meeres von einem Unbekannten*. Greek and German. Leipzig 1883. p. 188. — Vincent, *Commerce and Navigation of the Ancients in the Indian Ocean*. London 1807. Vol. 2, pp. 458 and 754.

²⁾ Zosimi *Comitis et exadvocati fisci Historiæ novæ libri septem*. Basilicæ. Lib. V, cap. 41. Gregorovius, *Geschichte der Stadt Rom im Mittelalter*. Hodgkin, *Italy and her Invaders*. London 1880. p. 347.

³⁾ Wilt. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 1, p. 99; vol. 2, pp. 458 and 754.

⁴⁾ Pardessus, *Diplomata, chartæ etc.* Paris 1849. Tom. 2, p. 309. — W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 1, p. 99.

⁵⁾ Jaffé, *Bibliotheca rerum germanicarum*. Berlin 1866. Vol. 3, pp. 156, 157, 199, 218 and 231.

⁶⁾ W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 1, p. 634.

by the Portugese under the leadership of Vasco da Gama in 1498. The cultivation of the pepper plant having been spread over several islands of the Malay archipelago, the production of pepper was greatly increased. This resulted in a larger export with the consequent reduction in price and increased consumption. The discovery of an all water route naturally deviated the spice trade from Venice which then was a commercial republic at its prime. In 1504, Portugese vessels laden with pepper sailed up the Thames and embarked at London and in 1522 they also entered the harbor of Antwerp. In spite of all the endeavors of the Venetian captains of commerce, the trade in pepper became a Portuguese monopoly¹⁾ from that time on, and remained such nearly up to the 18. century.

The estimate in which pepper was held during the middle ages is indicated by the fact that it was symbolic for the entire spice trade. Already in Rome the spice peddlers were known as *Piperrarii*. Later in France they were called *Pebriers*, and in England *Pepperers*.²⁾

In all probability, oil of pepper was known during the middle ages. It is first mentioned, however, by Saladin.³⁾ It was first described by Valerius Cordus⁴⁾ and later by Giov. Batt. Porta.⁵⁾ The method of distillation of the oil is first described by Winther⁶⁾ of Andernach, who, about 1550, distilled the oils of pepper, cinnamon, cloves, etc. The *Dispensatorium Noricum* of 1589 was the first of the pharmacopœias to include the oil. It is also enumerated in the municipal pharmaceutical price ordinance of Berlin of 1574, also in that of Frankfurt of 1688.⁷⁾

¹⁾ W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 2, pp. 502-527.

²⁾ *Ibidem*, vol. 2, pp. 634-640.

³⁾ Saladini Asculani *Compendium aromatariorum*. Venetii 1488. Index.

⁴⁾ Val. Cordi *Annotationes in Pedacei Dioscoridis Anazarbei de materia medica libros quinque. De artificiosis extractinnibus*. Editio Gesner. Argentorati. 1561. fol. 226.

⁵⁾ Porta: *Magiæ naturalis libri viginti. Liber de destillatione*. 1567. p. 379. Editio 1589, p. 184.

⁶⁾ Guintheri Andernacensi *de medicina veteri et nova*. Basil. 1571. pp. 630-635.

⁷⁾ H. A. van Rheede tot Draakestein. *Hortus indicus malabaricus*. Vol. 7, p. 14. "*Oleum ex pipere destillatum levem piperis odorem spirans, saporis parum acris*."

The first chemical investigations of pepper were conducted by Caspar Neumann¹⁾ and H. D. Gaubius,²⁾ later ones by Willert,³⁾ Oerstedt,⁴⁾ and Pelletier.⁵⁾

PEPPER OIL FROM LONG PEPPER.

Long pepper was used in antiquity both as spice and as medicament. It is mentioned in a number of mediæval drug lists.⁶⁾ Presumably, however, it never was in general use and in recent times it has come into disuse.

Distilled oil of long pepper is first mentioned in pharmaceutical price ordinances in 1589. It was included in the 1589 edition of the *Dispensatorium Noricum*. The first chemical examination of long pepper was made by Winkler⁷⁾ in 1827.

OIL OF CUBEBS.

Apparently cubebs were used as spice in China and in India during antiquity.⁸⁾ As medicament they appear to have first been used by the Arabians.⁹⁾ Kurbab¹⁰⁾ of Mesopotamia and Madusi¹¹⁾ of Bagdad, travelers living in the 9. and 10. centuries, mention cubebs among the more important spices. Edrisi,¹²⁾ a

¹⁾ C. Neumann, *Gründliche mit Experimenten erwiesene Chymie*. Editio C. H. Kessel. 1749. Vol. 2, Pte. 4, p. 9.

²⁾ Gaubii *Adversariorum varii argumenti liber unus*. 1771. Cap. 5, p. 55.

³⁾ Trommsdorff's Journ. der Pharm. 20, II. (1811), 44.

⁴⁾ Schweigger's Journ. für Chemie und Physik 29 (1819), 80.

⁵⁾ Trommsdorff's Neues Journ. der Pharm. 6, II. (1822), 233.

⁶⁾ Macer Floridus, *De viribus herbarum una cum Walafride Strabonis, Othonis Crenonensis et Joannis Folcz carminibus similis argumenti*. Editio Choulant. Lipsiæ 1832. p. 114. Simon Januensis, *Synonyma medicinarum seu Clavis sanationis*. Veneti 1510. Bonaini *Statuti inediti della città de Pisa*. 1857. Vol. 3, p. 492. -- Kunstmann, *Kenntnis Indiens im 15. Jahrhundert*. Munich 1863. p. 40. Saladin *Compendium aromatariorum*, Bononiensi 1488. Index.

⁷⁾ Arch. der Pharm. 21 (1828), 89.

⁸⁾ Alexandri Tralliani *Opera*. Edit. Puschmann. Vol. 2, p. 396.

⁹⁾ Paulus Aegineta. -- Editio Fr. Adams. London 1847, Vol. 3, p. 455.

¹⁰⁾ Khordadbeh, *Le livre des routes et des provinces par Barbier de Meynard in the Journal asiatique* 5 (1865), 294.

¹¹⁾ Meynard and de Courteille, *Praines d'Or*. Paris 1861 1877. Tom. I. p. 367 and Tom. IV, p. 78.

¹²⁾ Amédée Jaubert, *Géographie d'Edrisi* 1836. Tom. I, p. 51 and 89.

Sicilian geographer of the 12. century mentions cubebs among the spices imported via Aden. The abess Hildegard¹⁾ and the Danish cannon Henrik Harpestreng²⁾ describe cubebs as a valuable remedy. During the 13. century cubebs were used generally in Europe both as spice and as medicament. As such they are mentioned from the 14. century on in medical writings and municipal price ordinances.³⁾

Later the use of cubebs as spice declined. Indeed they had almost been forgotten when at the beginning of the past century their use was again urged by English physicians.⁴⁾

Cubebs were examined chemically by G. Wedel⁵⁾ in 1704, soon thereafter by Caspar Neumann,⁶⁾ in 1810 by Trommsdorff⁷⁾ and in 1821 by Vauquelin.⁸⁾

The volatile oil of cubebs was known to Valerius Cordus⁹⁾ in 1540. In price ordinances it first occurs in that of Frankfurt-on-the-Main of 1582.

¹⁾ Hildegardis Abbatissæ *Subtilitatum diversarum naturarum creaturarum Libri novem*. Editio Migne. *Patrologiæ cursus completus*. Tom. 197 (1855), p. 1147. Meyer, *Geschichte der Botanik*. Vol. 3, p. 537.

²⁾ Harpestreng, *danske Laegehug fra det trettende Aarhundrede, foerste Gang utgivet efter et Pergamenthaandskrift*. Copenhagen. 1826. p. 62.

³⁾ *Monumenta Gildhallæ Londoniensis. Liber althus I*, p. 230. Capmany, *Memorias historicas sobre la Marina, Comercio y Artes de la Ciudad de Barcelona*. 1779. p. 44. Bourquetot, *Etudes sur les foires de la Champagne*. Mémoires de l'Institut. Tom. 5 (1865), p. 288. — Saladini *Compendium aromatariorum*. 1488. Hans Folcz, *Confectbuch vom Jahre 1480*. In Choulant's *Handbuch der Bücherkunde für die ältere Medicin*. 1832. p. 188. Rogers, *History of Agriculture and Prices in England*. Vol. 1, p. 627; vol. 2, p. 544. *Liber niger Scaccarii*. London 1771. Vol. I, p. 478. Val. Cordus, *Dispensatorium Noricum*. Edit. 1548. pp. 76, 77 and 327. Flückiger, *Dokumente zur Geschichte der Pharmazie*. 1876, 15, and *Die Frankfurter Liste* in the *Arch. der Pharm.* 201 (1872), 441 and 211 (1877), 101.

⁴⁾ Dictionary of the Indian Islands. London 1856. p. 117. — Edinburgh Medical and Surgical Journal 14 (1818), 32. Mérat et de Lens, *Dictionnaire universel de materia medica*. Tom. 5 (1833), p. 331.

⁵⁾ G. Wedel, *De cubebis*. Dissertatio. Jenæ 1705.

⁶⁾ Caspar Neumann, *Lectiones chymici de salibus alkalinois et de camphora*. Berlin. 1727.

⁷⁾ Trommsdorff's Journ. der Pharm. 20, 1. (1811), 69.

⁸⁾ Trommsdorff's *Taschenbuch für Chemiker und Pharmazeuten* 1822, 195.

⁹⁾ Valerii Cordi *Annotatiunes in Pedacei Dioscoridis de medica materia libros quinque longe alia quam antea sunt hac sunt evulgatae*. 1561. fol. 226.

OIL OF BETEL.

When and by whom betel oil was first distilled is not known: it is highly probable that the preparation of the oil by Kemp¹⁾ in 1885 was not the first. A superficial examination of Siam betel oil in the laboratory of Schimmel & Co.²⁾ in 1887 revealed the presence of a phenol in fraction 250—260, which seemed to correspond with eugenol. Eykman,³⁾ who in 1888 examined an oil distilled by himself in Java, found no eugenol, but a new phenol which he called chavicol. A second examination in the laboratory of Schimmel & Co. revealed the fact that Siam betel oil contains neither eugenol nor chavicol, but a third phenol, a previously unknown isomer of eugenol, which Bertram and Gilde-meister⁴⁾ in 1889 termed betel phenol.

OIL OF SWEET BIRCH.

Next to turpentine oil, the oils of sassafras, wintergreen and birch bark are among the first oils obtained by distillation in the United States. The similarity in odor and taste of birch bark oil with true oil of wintergreen from *Gaultheria procumbens* was known before 1818.⁵⁾ The chemical identity of the principal constituent of both, however, was demonstrated by Wm. Procter Jr.⁶⁾ of Philadelphia in 1843. As the demand for wintergreen oil increased and since wintergreen leaves were not as readily collected, sweet birch bark was distilled indiscriminately with wintergreen leaves or even distilled alone as substitute⁷⁾ so that the commercial natural oil is at present obtained almost exclusively from the bark of *Betula lenta*, L.

¹⁾ Dymock, Warden and Hooper, *Pharmacographia indica*. Part. VI, p. 188.

²⁾ Schimmel's Bericht October 1887, 34.

³⁾ Chem. Ztg. 12 (1888), 1338.

⁴⁾ Journ. f. prakt. Chem. II. 39 (1889), 349.

⁵⁾ Bigelow, American Medical Botany. Boston 1818. Vol. 2, pp. 28 and 241.

⁶⁾ Americ. Journ. Pharm. 15 (1843), 241.

⁷⁾ *Betula lenta* and *Gaultheria procumbens* grow together in the wooded mountainous regions of the North Atlantic states. In a report on the wintergreen oil industry, Kennedy of Pottsville, Pa. (Americ. Journ. Pharm. 54 [1882], p. 49) called attention to the fact that the cost of collection of birch bark was but 1/7 of that of wintergreen leaves; also that the yield of oil from the bark was about 0.25 p. c., whereas that from wintergreen was 0.80 p. c. According to these figures the cost of production of the oil from birch bark is but half as great as that of wintergreen leaves.

OIL OF HOPS.

As early as the middle ages hops were used for the aromatization of beer, being mentioned in literature since the 8. century.¹⁾ For medicinal purposes hops and their glands have been used only in more recent times. The medicinal use of lupulin was first suggested in 1820 by Ives,²⁾ a New York physician.

Apparently the volatile oil of hops was first distilled from the glands in 1821 by Payen and Chevallier.³⁾

OIL OF SANDALWOOD.

Because of its peculiar odor sandalwood from *Santalum album* was highly prized during antiquity in India and China. Of the useful woods it was the most durable because it is avoided by the white ant that destroys most other kinds of wood. In India it was therefore used for carving images of the deities, and temple decorations. Both in China and India it is used as incense in the cult of the dead and other religious worship.

Sandalwood is mentioned in the earliest Sanscrit literature and probably also in that of China. Yet it does not appear to have been an article of barter between India and China and the occident. To the Egyptians, however, it was known as early as the 17. century B. C. They obtained it from the countries lying between the gulf of Aden and the Persian bay, then known as the Punt or Phun.⁴⁾

The first mention of sandalwood during the Christian era occurs about the middle of the first century in the Periplus of the Red Sea;⁵⁾ somewhat later in the 5. century in the writings

¹⁾ Flückiger and Hanbury, *Pharmacographia*. 1879. p. 551.

²⁾ Silliman's Journal of Sciences and Arts 1820, 302.

³⁾ Journ. de Pharm. 8 (1822), 214 and 533.

⁴⁾ Dümichen, *Die Flotte einer ägyptischen Königin*. Leipzig 1868. Dümichen, *Historische Inschriften*. 1869. Dümichen, *Aegypten*. 1880. p. 100. In Oncken's *Allgem. Weltgeschichte*. -- Lieblein, *Handel und Schifffahrt auf dem roten Meere in alten Zeiten*. Christiania 1886. pp. 21 and 31. -- Quatremère, *Mémoires géographiques et historiques sur l'Egypte*. 1811. Vol. 2, pp. 366-375.

⁵⁾ *Periplus maris Erythræi*. Editio Fabricius. Leipzig 1883. p. 75. -- Vincent, *Commerce and Navigation of the Ancients in the Indian Ocean*. London 1807. Vol. 2, p. 378.

of Kosmas Indikopleustes.¹⁾ From that time on, sandalwood is mentioned by a number of writers and travelers: in the 9. century by Avicenna,²⁾ in the 10. century of Serapion³⁾ and by Masudi,⁴⁾ in the 11. century by Constantinus Africanus of Salerno⁵⁾ and in the 13. century by Marco Polo.⁶⁾ Saladin of Ascoli⁷⁾ in the 15. century distinguished between white, yellow and red sandalwood.⁸⁾ Barbosa⁹⁾ in 1511 makes a like distinction and adds that the white and yellow wood are obtained from the Malabar coast and cost ten times as much as the red. Rumpf¹⁰⁾ in 1741 was the first to give a good illustration of the tree.

Inasmuch as the volatile oil of sandalwood has come into use medicinally only in recent times, it is mentioned but seldom in mediæval works and in the later treatises on distillation.

¹⁾ *Christiania topographia*, in Mignes *Patrologiæ cursus completus. Series græca*. Vol. 88, pp. 574 and 446. Lassen, *Indische Alterthumskunde*. Vol. 3, p. 40. Meyer, *Geschichte der Botanik*. Vol. 2, p. 388.

²⁾ *Avicennæ libri in re medica omnes; latine redditi ab I. Paulo Mongio et I. Constantino recogniti*. 2 Vol. Venetiæ 1564. *Canon medicinarum*. Lib. II. tractat. II. Cap. 656.

³⁾ *Liber Serapionis aggregatus in medicinis simplicibus*. Mediolani 1473.

⁴⁾ Ali el Masudi, *Les Prairies d'Or*, texte et traduit par Meynard et P. de Courteille. 9 Vol. (the original Arabian text was completed in 984). Paris 1861 1877. Vol. 1, p. 222.

⁵⁾ *Constantini Africani Opera omnia*. Basilie 1536. *Liber de gradibus*. p. 369.

⁶⁾ Pauthier, *Le Livre de Marco Polo*. Paris 1865. Tom. 2, p. 580.

⁷⁾ *Compendium aromatariorum Saladini principis tarenti dignissimi medici diligenter correctum et emendatum*. 1488.

⁸⁾ It is not at all improbable that even during premediæval times the wood of the *Pterocarpus santalinus*, L., N. O. *Leguminosæ*, which tree is indigenous to the Southern parts of the East Indies and to the Philippines, was used on account of its red pigment. Inasmuch as it was imported from the same countries that yielded the fragrant sandalwood it was at first regarded as related to sandalwood and hence so designated. This error and with it the false designation has remained. In consequence many an author has placed them together, e. g. in the list of Frankfurt of 1450. Garcia da Orto recognised the mistake and called attention to it though in vain. (Ab Horto, *Colloquios dos simples e drogas he cousas medicinaes da India, e assi dalguas frutas achadas nellu ande se tratam*. 1563. Varnhagen's reprint 1872, p. 188. - Editio Carolus Clusius 1539, p. 68.)

⁹⁾ Ramusio, *Delle navigationi et viaggi*. Venetia 1554. fol. 357, 6.

¹⁰⁾ *Rumphii Herbarium Amboinense*. Amstelodami 1741. Vol. 2, p. 42.

Its distillation is recorded by Saladin,¹⁾ by Conrad Gesner²⁾ and by Friedrich Hoffmann.³⁾ The yield was first ascertained by Caspar Neumann and Dehne.⁴⁾ It was first examined by P. Chapoteaut.⁵⁾

It is reported that in Ceylon distilled oil of sandal-wood was used for the embalming of the dead bodies of princes as early as the 9. century.⁶⁾

OIL OF STARANISE.

Owing to its peculiarly shaped and aromatic fruits, the star-anise tree has no doubt been known since antiquity and has received attention. However, Chinese literature appears to contain little concerning its use. Under the Sung dynasty, between 970 and 1127, several of the southern Chinese provinces had to furnish star anise as tribute.⁷⁾ Into European commerce it was apparently introduced by the circumnavigator Thomas Cavendish, who in 1578 brought it to London from the Philippines. It was in London that the Leyden Professor Carolus Clusius first became acquainted with the fruit and described it as *Anisum philippinarum insularum*.⁸⁾ According to a statement by Redi, star-anise is supposed to have been known to the Italian drug trade as early as the middle of the 16. century under the name *Fœniculum sinense*,⁹⁾ but apparently was not used until the middle of the 17. century.

The volatile oil of staranise was distilled some time during the 18. century but was not used to any extent until the 19. century.

¹⁾ *Compendium aromatariorum* Saladini. 1488. fol. 349.

²⁾ *Ein köstlicher Schatz* Euonymi Philatri. 1555. p. 246.

³⁾ *Frederici Hoffmannii Observatorium physico-chemicarum selectionum*. Halæ 1722. Lib. III. Observ. I, p. 69.

⁴⁾ *Crell's Chemisches Journal* 8 (1780), 18.

⁵⁾ *Bull. Soc. chim.* II. 37 (1882), 303.

⁶⁾ Flückiger and Hanbury, *Pharmacographia*. II. edit., 599.

⁷⁾ Bretschneider, Study and value of Chinese botanical works. Foochow 1870. p. 14.

⁸⁾ *Clusii Rariorum plantarum historia*. Antwerp. 1601. p. 202.

⁹⁾ Redi, *Esperienze naturali*. Firenze 1671. p. 119. *Tavola 2.* — Latin edition: Redi, *Experimenta circa res diversas naturales, speciatim illas, quæ ex India adferuntur*. Amstelodami 1675. p. 172.

The chemical composition of staranise and the yield of oil were studied about the time by Caspar Neumann and Friedr. Cartheuser;¹⁾ somewhat later, *i. e.* in 1818, by W. Meissner.²⁾

OIL OF YLANG YLANG.

It is only since the beginning of the sixties of the past century that ylang-ylang oil is being distilled in the island of Luzon, P. I. The first to take up this distillation was F. Steck³⁾ a German apothecary in Manila, and the uncle of Pablo Sartorius, whose name is still associated with the firm that makes a speciality of this oil. Of the larger distillers of that early period, J. Witte and von Westernhagen should be mentioned.

In Europe it was the Parisian apothecary F. Rigand⁴⁾ who contributed to make known this oil. However, ylang-ylang oil did not become widely known until the world's fair in 1878, when it was exhibited in Paris by Oskar Reymann and Adolf Roensch of Manila.

OILS OF MACE AND NUTMEG.

Older literature contains no definite information pertaining to knowledge of or use made of nutmegs during antiquity. Statements, such as occur in the writings of Plautus, Scribonius Largus, Dioscorides, Pliny, Galen etc. that seem referable to mace, may as well be referred to the bark of *Ailanthus malabarica*, D. C., an East Indian tree.⁵⁾ Into western Europe the fruits were probably introduced by Arabian physicians.

About the year 1180 nutmegs are enumerated among the spices imported into Accon, the port of southern Syria.⁶⁾ In

¹⁾ F. A. Cartheuser, *Elementa chymix-medix dogmatico-experimentalis; una cum synopsis materiæ medicæ selectioris*. Halæ 1736. Vol. 2, p. 327.

²⁾ *Chemische Untersuchung des Sternanis*. Buchholz, *Taschenbuch für Scheidekünstler und Apotheker auf das Jahr 1818 und 1819*, 1.

³⁾ Pharm. Zentrallh. 9 (1868), 46.

⁴⁾ *Ibidem* 7 (1866), 478.

⁵⁾ Acosta, *Tractato de las drogas y medicinas de las Indias orientales*. Burgos 1578. p. 40. Méral et De Leus, *Dict. de Materia medica*. 1832. Vol. 4, p. 173.

⁶⁾ *Recueil des Historiens des Croisades*. Lois. 1843. p. 173. — W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 2, p. 624.

1158 *nuces muscatarum* from Alexandria were articles of commerce in Genoa.¹⁾ At that time they were evidently prized for fumigating purposes.²⁾ From that time on, nutmegs were found in all of the larger marts and soon became one of the most precious spices. Their geographic source, however, apparently first became known through the travelers Lodovico Bartheima and Pigafetta³⁾ in the beginning of the 16. century.

It was about this time that the Portuguese, having taken possession of the Spice Islands, made a monopoly of nutmegs and other indigenous spices. A century later, when in 1605 the Portuguese were driven out by the Dutch, the latter attempted to concentrate the production and commerce of nutmeg to a few islands, notably on Banda and Amboina. With this in view they destroyed the spice-producing trees and shrubs on the most productive islands and forbade their cultivation.⁴⁾ This interdiction was not removed until 1863. In 1769 the French succeeded in transplanting the nutmeg tree to Mauritius and at the beginning of the 19. century the English began its cultivation in Benkulen (Sumatra) and Penang.

Until recently nutmeg and mace belonged to the most expensive spices. With the cultivation of the nutmeg tree in Dutch, English and French colonies, nutmegs became more plentiful and hence cheaper.

The distilled oils of nutmeg and mace were well known to the authors of the treatises on distillation that appeared during the middle of the 16. century and later. Valer. Cordus,⁵⁾ Walter Ryff,⁶⁾ Conrad Gesner,⁷⁾ Porta,⁸⁾ Winther⁹⁾ and others make repeated mention of both oils.

¹⁾ *Historia Patriæ monument.* Chartæ II. Torino 1853. fol. 514.

²⁾ Petrus de Ebulo, *Carmen de motibus sicilicis.* Basilæ 1746. p. 23.

³⁾ Ramusio, *Delle navigationi et viaggi.* Venetia 1554. fol. 183 and fol. 389b.

⁴⁾ Hasskarl, *Neuer Schlüssel zu Rumphs Herbarium amboinense.* Halle 1866. Vol. 2, p. 17.

⁵⁾ Valer. Cordi *Annotationes in Pedanii Dioscoridis de Materia medica libri V. De artificiosis extractionibus liber.* 1540. fol. 226.

⁶⁾ Gualtherius Ryff. *New gross Destillirbuch.* Editio Frankfurt a. Main 1556. fol. 181. 1888.

⁷⁾ Euvonymi Philatri *Ein köstlicher Schatz* etc. 1555. p. 215.

⁸⁾ Porta *Magiæ naturalis libri 20. Libri de destillatione.* Pars I, p. 378.

⁹⁾ Guintheri Andernacei *de medicina veteri et nova.* Basilæ 1571. p. 630 - 635.

Both oils are first mentioned in pharmaceutical price ordinances of Berlin of 1574, of Frankfurt and of Worms of 1582, and in the 1589 editions of the *Dispensatorium Noricum*.

These oils were first examined by Caspar Neumann,¹⁾ Conrad Mich. Valentine²⁾ and Bonastre.³⁾

OIL OF CAMPHOR.

In China, camphor has been prepared and used in early antiquity. The first documental reference to it is found in the writings of the Arabian prince Imru-1-Kais of the sixth century;¹⁾ also in the Koran, in which it is mentioned as a refrigerant in connection with the beverages of the blessed in paradise.²⁾ Aetius of Amida, also in the sixth century, mentions camphor as a remedy.³⁾ When the palace in Madain of Choroës II. king of the Sassanidae was pillaged in 636, much camphor was taken in addition to musk, amhra, sandalwood and other oriental aromatics.⁴⁾ Later, when Arabian sailors and merchants sailed to India and China, they became acquainted not only with the principal ports via which the camphor was shipped from south-eastern Asia to the Mediterranean countries, but also with the sources of supply. Thus the Arabian merchants and physicians became acquainted with the different varieties which entered the world's market in part from China, in part from Sumatra. Marco Polo, in the 13. century, also became acquainted with the camphor in Sumatra and Borneo.⁵⁾

¹⁾ Neumann, *Chymia medica dogmatico-experimentalis*. Züllichau 1749. Vol. 2, Part 3, p. 437.

²⁾ *Macis vulgo sed peperam, Muskatenblume dicta*. Dissertatio. Giessen 1719.

³⁾ Trommsdorff's Neues Journ. der Pharm. N. II. (1824), 231.

⁴⁾ In Ibn Hagik al Hamdany's manuscript on the description of Arabia, p. 170, and Flückiger's *Pharmacognosie*, p. 159.

⁵⁾ *Le Koran, traduit par Kasimirski*. Cap. 76. V. 5 and 6.

⁶⁾ Aetii ab Amida medici graeci ex veteribus medicinarum Tetrabiblos. Editio Frohen. Basiliae 1542. p. 92b.

⁷⁾ Weil, *Geschichte der Chaliten*. Mannheim 1846. p. 75.

⁸⁾ Yule, *Book of Ser Marco Polo*. London 1871. Vol. 2, p. 185. — Pauthier, *Le livre de Marco Polo*. Paris 1865. Vol. 2, p. 577. — Masudi, *Prairies d'Or*. Editio Meynard et de Courteille. Paris 1861. Vol. 1, p. 367. — Ritter's *Erdkunde von Asien*. 1834. Vol. 3, pp. 858–881.

The preparation of camphor in Japan was first described by Engelbert Kaempfer.¹⁾ Probably the Japanese learned the method of preparation from the Koreans. It is said to have first been introduced into the province Satsuma on Kiuschiu and later spread over the rest of Kiuschiu and over Schikoku and other parts of Japan.²⁾ The age of the production of camphor in Formosa is unknown. Klaproth³⁾ who visited the island at the beginning of the past century refers to the production of camphor as one of the principal industries of Formosa. Since the occupation of the island by the Japanese, the distillation of camphor has been increased materially.

In medical practice camphor was known to the Arabians. In Italy it was used during the 11. century and in Germany during the 12. century.

Camphor oil was first brought to Europe in 1884. As principal constituent of the oil, Schimmel & Co. discovered safrol and isolated it on large scale.

OILS OF CASSIA AND CEYLON CINNAMON.

The cassia bark of China and the cinnamon bark of the Indian archipelago are among the longest known and used spices. Cassia is mentioned in the earliest herbals and medical treatises of China,⁴⁾ about 2500 B. C., and as early as the 17. century B. C., it appears to have been used by the Egyptians.⁵⁾ It is also mentioned in most of the writings of antiquity. Thus in addition to other spices it is mentioned in Sanskrit literature and in the Old Testament.⁶⁾

¹⁾ E. Kämpfer, *Amoenitates exoticæ*. Lemgo 1712. p. 772. (With an illustration of the tree.)

²⁾ James W. Davidson, *The Island of Formosa*. London and New York 1903.

³⁾ Klaproth, *Memoires relatifs à l'Asie*. Paris 1824.

⁴⁾ Bretschneider, On the study and value of Chinese botanical works, with notes on the history of plants and geographical botany from Chinese sources. Foochow 1870.

⁵⁾ Dümichen, *Die Flotte einer ägyptischen Königin*. Leipzig 1868. — Schumann's *Kritische Untersuchungen über die Zimtländer*. *Ergänzungsheft No. 73 zu Petermann's Mitteilungen*. Gotha 1883. p. 11.

⁶⁾ Exodus, 30: 23 and 24. — Psalms, 45: 9. Jeremiah, 6: 20. Heseekiah, 27: 19. — Proverbs, 7: 17. Song of Solomon, 4: 14. — Jesus Sirach, 24: 20 and 21. — Apocalypse, 18: 13.

As its geographical source, mythical countries are mentioned; also and this, no doubt, because of the customary commercial routes¹⁾ Arabia and Ethiopia.²⁾ At the time of the Hebrews the commerce in cinnamon was largely in the hands of the Phœnicians.³⁾ In order to guard their own interests, the Phœnician merchants did not correct these erroneous surmises and statements. Hence for centuries the real source of cassia remained undecided.

Both Greeks and Romans knew and used cinnamon. The Arabians introduced it into western Europe. From the 8. century on, it was a well known though costly spice. As such it is frequently mentioned among the presents given by princes to each other or to the pope.⁴⁾ During the 12. and 13. centuries both Chinese and Ceylon cinnamon were common articles of the Levant trade⁵⁾ and in the eastern ports of the Mediterranean. From the 15. century on, both were current articles in apothecary shops.⁶⁾

Later when the more expensive Ceylon cinnamon was also brought into the European market, the two kinds were frequently

¹⁾ Historical introduction, p. 5.

²⁾ Dümichen, *Die Flotte einer ägyptischen Königin*. 1868. — Dümichen, *Historische Inschriften*. 1869. — Dümichen, *Ägypten in Onchens Allgemeiner Weltgeschichte*. 1880. p. 100. — Herodoti *Historiarum libri*. Lib. 1, 107 and 110. Lib. 3, 110 112. — Theophrasti *Historia plantarum*. Lib. 9, 4-5. — Arriani *Anabasis*. Lib. 7, 20 and 21. — *Fragmenta historicorum græcorum. De mari Erythæo*. p. 97. — Dioscoridis, *De medica materia libri quinque*. Lib. 1, 12 and 13. Editio Kühn-Sprengel 1829. Vol. 1, p. 23. — Plinii *Naturalis historie libri*. Lib. 12, 41 43 and 46. — *Periplus maris Erythræi*. Editio Fabricius. 1883. pp. 47 and 51. — A. H. L. Heeren, *Ideen über die Politik, den Verkehr und den Handel der vornehmsten Völker der alten Welt*. Göttingen 1796. Vol. 2, pp. 611 613. — Meyer, *Geschichte der Botanik*. Vol. 2, p. 86.

³⁾ See pp 5 and 6. — Lassen, *Indische Alterthumskunde*. Bonn 1847. Vol. 1, p. 280.

⁴⁾ *Libri pontificis*. Editio Duchesne. Paris 1886. Vol. 1, p. 177. — *Parlessus, Diplomata chartæ etc.* Paris 1849. Vol. 2, p. 309 — Jaffé, *Bibliotheca rerum Germanicarum*. 1886. Vol. 3, p. 218.

⁵⁾ See p. 11.

⁶⁾ Fr. Bald. Pegolotti, *La pratica della mercatura*. In Pagnini *Della decima e delle altre gravanze etc.* Lisboa e Lucca. 1766. pp. 27, 44, 49, 64. — Joh. de Garlandia, *Dictionnaire*. Editio Schéler in *Lexigraphie latine du 12. et 13. siècle*. p. 28.

confounded. Garcia ab Orta in 1536 was the first to distinguish definitely between the two kinds.¹⁾ In the accounts of the Portuguese, who under Vasco da Gama touched at Ceylon in 1498, mention is made of cinnamon as one of the products of the island, without, however, regarding it as better than the Chinese cinnamon previously known to them.²⁾ Even later most of the cinnamon that was imported over the water route via Ceylon into the ports of the Erythræan and Red seas, appears to have been Chinese cinnamon. Ceylon cinnamon was originally collected in the forests of the interior of the island. This product was in no way the equivalent of the present-day bark, obtained by rational peeling from improved plants. These improved methods of production appear to have been introduced toward the close of the 16. century.³⁾ After the occupation of Ceylon by the Dutch in 1556, one of the governors greatly improved the cultivation of cinnamon. As a result they soon were in a position to supply the European market with a bark that was superior to the wild product.⁴⁾ After the occupation of the island by the British in 1796, the cultivation of and commerce in cinnamon became the monopoly of the British East India Company. The monopoly lasted until 1833.⁵⁾ This company levied an export duty and thus injured the Ceylon trade causing the Dutch to cultivate cinnamon in Java and Sumatra.

When in the course of the fifteenth century the distillation of aromatic waters for medicinal purposes became a common practice,⁶⁾ cinnamon bark was undoubtedly distilled for the preparation of its water. The Canon St. Amando of Doornyk living

¹⁾ Garcias ab Horto, *Colloquios dos simples e drogas he cousas medicinaes da India* etc. 1563. Editio f. A. von Varnhagen. 1872. p. 63. — Editio Clusius, *Aromatum et simplicium aliquot medicamentorum apud Indos nascentium historia*. Antverpiæ 1593. p. 60.

²⁾ Odoardo Barbosa in Ramusio *Delle navigationi et viaggi*. 1554. Editio Hakluyt Society, London 1866. "East Indies."

³⁾ Lettera di Filippo Sassetti a Francesco I. di Medici, *Storia dei viaggiatori italiani*. Leghorn 1875. p. 367.

⁴⁾ J. A. Murray, *Apparatus medicaminum tam simplicium quam præparatorum et compositorum*. 1787. Vol. 4, p. 421. — Nees von Esenbeck, *Amoenitates botanicæ Bonenses*. 1823. Fasc. 1.

⁵⁾ Sir James Emerson Tennent, *Ceylon, an account of the island, physical, historical and topographical*. 5th edit. London 1860. Vol. 2, p. 164.

⁶⁾ See p. 39.

toward the end of the 15. century seems to have been the first to isolate oil of cinnamon¹⁾ in addition to bitter almond oil and oil of rue, and several other volatile oils. Valerius Cordus had prepared the oil about 1540.²⁾ At that time it may already have found application in medicine, so that it was included in the first edition of the *Dispensatorium Noricum*. Lonicer soon afterward distilled the oils from the spices, among them cinnamon oil, in a new peculiar apparatus.³⁾ In the price ordinances cinnamon oil is first mentioned in that of Berlin of 1574, also in that of Frankfurt-o.-M. of 1582.

Winther of Andernach⁴⁾ distilled and described the oil in 1570, and G. B. Porta in 1589.⁵⁾

The early observations made on cinnamon oil were restricted mainly to the crystalline deposit formed upon prolonged standing. Such crystal formations were observed (among others) by Ludovici⁶⁾ about 1670, later by Slare in England,⁷⁾ by Boerhaave⁸⁾ and Gaubius⁹⁾ in Holland. The latter regarded them as camphor; Du Menil¹⁰⁾ and Stockmann¹¹⁾ supposed them to be benzoic acid, Dumas and Péligot¹²⁾ in 1831 recognized them to be cinnamic acid. C. Bertagnini prepared pure cinnamic aldehyde in 1852.¹³⁾

¹⁾ See p. 33.

²⁾ Valerius Cordus, *De artificiosis extractionibus liber*. Edit. Gesner. Argentor. 1561. fol. 226.

³⁾ See the next chapter.

⁴⁾ Guintheri Andernacei *Liber de veteri et nova medicina*. Basilæ 1571. pp. 630-635.

⁵⁾ G. B. della Porta, *Liber de distillatione*. Romæ 1563. fol. 75.

⁶⁾ *Phlegmerides medico-physicæ Academiæ naturalis, Curiosorum observationes* 145. p. 378.

⁷⁾ Philosophical Transactions of the Royal Society of London. Vol. 3 (1686), p. 362.

⁸⁾ Boerhaave, *Elementa chemiæ* etc. Lugduni Batavorum 1732 Vol. 1, p. 106. Vol. 2, pp. 114 and 121.

⁹⁾ Gaubii *Adversariorum varii argumenti liber unus*. Leydæ 1771. p. 29.

¹⁰⁾ Buchner's Repertor. der Pharmacie 5 (1819), 1. — Schweigger's Journal für Chemie und Physik 2f (1819), 224.

¹¹⁾ Trommsdorff's Neues Journ. der Pharm. 14 (1827), 237.

¹²⁾ Annal. de Chim. et Phys. 11. 57 (1834), 305. — Liebig's Annalen 14 (1835), 50.

¹³⁾ Liebig's Annalen 25 (1853), 271.

The yield of volatile oil from cassia and cinnamon barks was determined by the following observers: G. W. Wedel¹⁾ in 1707; Friedr. Cartheuser,²⁾ Caspar Neumann³⁾ and Phil. F. Gmelin⁴⁾ in 1763; J. F. A. Goettling⁵⁾ about 1803; by Dehne⁶⁾ about the same time; also by Buchholz⁷⁾ in 1813.

OIL OF SASSAFRAS.

As already mentioned under the oils of sweet birch and wintergreen,⁸⁾ next to turpentine oil, the oil of sassafras was the first volatile oil distilled in North America. On account of the pleasant aroma, the root bark known as *Pavane* was chewed by the natives. It was also mixed with smoking tobacco⁹⁾ and added as aromatic to refreshing beverages and was used as a remedy. On account of its peculiarity, the sassafras tree is said to have attracted the attention of the Spaniards at their first landing in Florida under Ponce de Leon in 1512, also under de Soto in 1538. They are said to have regarded it as a kind of cinnamon tree. Afterward the sassafras tree soon came to be regarded as a valuable medicinal plant¹⁰⁾ and article of luxury of the new world. In Mexico it had long been regarded as such.¹¹⁾ As late as the first half of the 19. century the bark, leaves and

¹⁾ Wedel, *De cinnamomo*. Dissertatio. Jenæ 1707.

²⁾ Cartheuseri *Elementa chymiae dogmatico-experimentalis*. Halæ 1736. Vol. 1, p. 127; vol. 2, pp. 109 and 187.

³⁾ Neumannii *Chymia medica dogmatico-experimentalis*. Editio Kessel. Züllichau 1750. Vol. 2, pars 2, p. 20.

⁴⁾ Philipp F. Gmelin, *De analepticis quibusdam nobilioribus et cinnamomo*. Dissertatio. Tübingen 1763.

⁵⁾ J. F. A. Göttling, *Analyse der Cassienzimrinde*. Buchholz Taschenbuch für Scheidekünstler und Apotheker 1804, 1.

⁶⁾ Neues Berl. Jahrbuch für Pharmacie 1805, 289.

⁷⁾ Buchholz Taschenbuch für Scheidekünstler und Apotheker 1814, 1.

⁸⁾ See p. 118.

⁹⁾ C. S. Rafinesque, *Medicinal Flora or Manual of the Medical Botany of the United States of North America*. 1830. Vol. 2, p. 235.

¹⁰⁾ Monardes, *Historia medicinal de las cosas que se traen de nuestras Indias occidentales qui sirven en medicina*. Sevilla 1574. p. 51. Editio latina Clusii. Antverpiæ 1593. pp. 355--359.

¹¹⁾ Joannis de Laet, *Americæ utriusque descriptio, Novus Orbis, seu descriptionis Indiæ occidentalis libri 18* Lugduni Batav. 1633. p. 215.

buds were used in the middle and central states as a substitute for Chinese tea.¹⁾

As early as 1582 sassafras wood and bark became known in Germany as a new American drug and were used under the name of *Lignum pavanum*, *Lignum floridum*, *Lignum xylo-marathrum* (*Fenchelholz*).²⁾ In 1610 young plants were brought to England and cultivated.³⁾ Bark and wood were apparently first distilled in 1620 by Angelus Sala of Vicenza, who as body physician to the Duke of Mecklenburg, lived in Schwerin from 1610—1639, and who mentions that the oil is heavier than water.⁴⁾ Schröder's *Pharmacopœa medico-chymica*, published in Frankfurt-on-the-Main in 1641, is the first pharmacopœia that gives directions for the distillation of the oil, whereas the municipal price ordinance of Frankfurt-on-the-Main of 1587 already enumerates *Oleum ligni sassafras*. Friedrich Hoffmann in Halle distilled the oil in 1715 and describes it as being colorless and specifically heavy.⁵⁾ In 1738, John Maud, an Englishman, observed the formation of large crystals of sassafras camphor.⁶⁾ Early examinations of the oil were made by Muschenbroeck, by Caspar Neumann,⁷⁾ and by Dehne.⁸⁾ The first thorough investigation was made by Grimaux and Ruotte⁹⁾ in 1869.

Detailed and definite statements concerning the medicinal use of sassafras bark and wood appear to be wanting in American literature. This is also true of the early distillation of the oil. Aside from the communications by Monardes, De Laet and others, one of the first references to these drugs is found in the list of drugs mentioned on p. 94 (footnote 7), as having been im-

¹⁾ J. U. Lloyd, Historical study of Sassafras. Pharmac. Era (New York), 20 (1898), 608.

²⁾ Flückiger, *Dokumente zur Geschichte der Pharmacie*. Halle 1876. pp. 30—31.

³⁾ Flückiger and Hanbury, *Pharmacographia*. 1879. p. 537.

⁴⁾ Sala, *Opera physico-medica. Hydrelæologia*. Rostock 1639. p. 84.

⁵⁾ Fr. Hoffmannii *Observationes physico-chymicæ. Observatio 1. De oleis destillatis inque eorum destillatione observanda*. pp. 13—14.

⁶⁾ Philosophical Transactions of the Royal Society. London, 8 (1809), 243.

⁷⁾ Caspar Neumann, *Chymia medica dogmatico-experimentalis*. 1749. Vol. 2, pars 3, p. 248.

⁸⁾ Pfaff, *System der Materia medica*. 1815. Vol. 4, p. 242.

⁹⁾ Compl. rend. 68 (1869), 928.

ported from the "Province of Virginia" into England in 1610. More than a century later it is again mentioned in the reports on his travels made by the Swedish botanist Peter Kalm, who in 1748—1749 traveled through the north Atlantic provinces of the then English colony as far as Montreal and Quebec. He found the sassafras tree widely distributed in Pennsylvania, New Jersey and New York.¹⁾ Kalm also mentions that the bark and wood are used for flavoring rootbeer and brandy, also universally as medicament. In the distillation of brandy, bark and root are distilled with the brandy.²⁾

With the Indians, sassafras was highly reputed as blood purifier.³⁾ Later the colonists used it in the preparation of their domestic remedies.

It is unknown when the distillation of sassafras oil had its beginning, though this was probably at the beginning of the 19. century. This much at least is true that Joh. David Sehcepf, an experienced physician and careful observer, who in 1783 and 1784 traveled through the Atlantic states of the Union alludes on several occasions in his reports to the wide distribution of the sassafras tree, but apparently has not heard of the distillation of sassafras.⁴⁾

OIL OF BAYBERRY.

In classical antiquity the laurel, *Laurus nobilis*, L., was utilized as symbol of victory and fame⁵⁾ but found no other use than that of a decorative plant. During the middle ages its bark and leaves were used medicinally.

The mixture of fatty and volatile oil, or butter, the *oleum laurinum* obtained by boiling the fruits with water was used

¹⁾ Peter Kalm, *Beschreibung der Reise nach dem nördlichen Nordamerika im Jahre 1748-1749*. German translation. Göttingen 1754. Vol. 3, p. 355.

²⁾ *Ibidem* vol. 2, p. 482.

³⁾ C. S. Rafinesque, *Medicinal Flora or Manual of the Medical Botany of the United States of North America*. 1830. Vol. 2, p. 235.

⁴⁾ Johann David Schöpf, *Reise durch die mittleren und südlichen Vereinigten nordamerikanischen Staaten, nach Ost-Florida und den Bahama-Inseln in den Jahren 1783—1784*. Erlangen 1788. Vol. 1, p. 415.

⁵⁾ Hehn, *Kulturpflanzen und Haustiere in ihrem Übergang aus Indien nach Griechenland und Italien*. 3rd ed. 1877. pp. 196—201.

during antiquity. In the older literature it is enumerated among the substances used for anointing and for medicinal purposes,¹⁾ also among the aromatics.²⁾ It found a place in the first edition of the *Dispensatorium Noricum* of 1543.

The volatile oil of the fruits appears to have been used formerly for medicinal purposes. At least it is included in the price ordinance of Frankfurt of 1582 and in others of a later date.

OIL OF SPOONWORT.

During the middle ages spoonwort was regarded as a remedy against scurvy. As such it is mentioned in older treatises on medicine and distillation. It was pictured in Joh. Wier's³⁾ treatise on scrofula in 1567. The distilled oil of spoonwort seems to have been known and to have been used medicinally since the middle of the sixteenth century. This use, however, does not appear to have been general, for the oil is not mentioned in any edition of the *Dispensatorium Noricum*, neither in the *Pharmacopœa Augustana* nor in Schröder's *Pharmacopœa medico-physica* of Frankfurt-on-the-Main. It occurs, however, in the municipal ordinance of Frankfurt of 1587. Later it occurs also in inventories of apothecary shops of Braunschweig and Dresden of 1640 and 1683 respectively.⁴⁾ At the beginning of the eighteenth century it was distilled by Friedr. Hoffmann in Halle and described by him.

OIL OF MUSTARD.

Mustard seed was known during antiquity and was esteemed for one reason or another as becomes evident from the symbolic references made to it in the New Testament.⁵⁾ It appears to

¹⁾ Dioscorides, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 53. Palladius, *De re rustica*. II. 7. Editio Nisard. p. 554. Plinii *Naturalis historiae libri*. Lib. 7. Editio Littré. Vol. 1, p. 548. - Hildegardis Abbatisæ *Physica*. Editio Migne. *Patrologiæ Cursus completus*. Vol. 197. 15, p. 1228.

²⁾ Douët-d'Arcq, *Comptes de l'Argenterie des rois de France au XIV^{me} siècle*. 1851. Vol. 1, p. 207.

³⁾ Joh. Wier (Piscinarius), *Medicarum observationum rararum liber*. Basilæ 1567. pp. 32-34.

⁴⁾ Flückiger, *Dokumente zur Geschichte der Pharmacie*. 1876.

⁵⁾ Matth., 13:31. Luke, 13:18 and 19.

have been utilized first as spice,¹⁾ and later also as external remedy. As the latter it is referred to by Theophrastus,²⁾ Dioscorides,³⁾ Pliny,⁴⁾ Scribonius Largus⁵⁾ and Alexander Trallianus. In the writings of Columella are found the oldest directions for the preparation of table mustard.⁶⁾ About the year 800 mustard was cultivated in the neighborhood of Paris.⁷⁾ Its cultivation was directed by Charlemagne in his *Capitulare* of 812.⁸⁾ In Spain it was cultivated by the Arabians.⁹⁾ From here its cultivation spread to Germany and France in the 10. century and thence to England¹⁰⁾ during the 12. century.

The first statement which indicates a knowledge of the fact that mustard oil can be obtained by distillation with water, is found in the writings of Porta;¹¹⁾ another in the writings of the Parisian apothecary Nic. le Febvre.¹²⁾ Boerhaave, however, seems to have been the first to prepare the volatile mustard oil in 1732 and to have called attention to its properties.¹³⁾ That it contains sulphur was observed by Thibierge of Paris in 1819.¹⁴⁾ Boerhaave and Murray¹⁵⁾ observed the great density of the oil;

¹⁾ Mommsen, *Berichte der Sächsischen Gesellschaft der Wissenschaften*. Leipzig 1861, 1—80.

²⁾ Theophrasti *Eresii opera, quæ supersunt, omnia*. Editio Wimmer. 1866. p. 109.

³⁾ Dioscoridis *de materia medica libri quinque* in Kühn-Sprengel. *Medicorum graecorum opera quæ extant* 1829. Vol. 1, p. 52, 191 and 293.

⁴⁾ Plinii *Naturalis historia libri*. Lih. 19, p. 54 and Lib. 20, p. 87.

⁵⁾ Scribonii Largi *Compositiones medicamentorum*. Editio Helmreich. 1887. 9, p. 56.

⁶⁾ Columellæ *De re rustica et de arboribus*. Editio Nisard. 1877. p. 493.

⁷⁾ Guérard, *Polyptique de l'abbé Irminon*. Paris 1844. p. 716.

⁸⁾ *Capitulare de villis et cortis imperialibus*. Explained by A. Thier in Fühling's *Landwirtschaftliche Zeitung*. Berlin 1878, 241—260.

⁹⁾ Dozy, *Le Calendrier de Cordue de l'année 961*. Leyde 1873.

¹⁰⁾ Rogers' *History of agriculture and prices in England*. 1866. p. 223. — *Pharmaceutical Journ.* III, 8 (1878), 852.

¹¹⁾ Porta: *Magia naturalis libri viginti. Liber de destillatione*. Romæ 1608. p. 153.

¹²⁾ N. le Febvre, *Traité de la Chymie*. Paris 1660. Tom. 1.

¹³⁾ Boerhaave, *Elementa chemiæ, quæ anniversario labore docuit in publicis privatisque scholis*. Lugduni Batavorum 1732. Editio Londini. 1732. Pars 2, p. 38.

¹⁴⁾ *Journ. de Pharm.* 5 (1819), 20, 439 and 446. Trommsdorff's *Neues Journ. d. Pharm.* 4, II. (1820), 250.

¹⁵⁾ J. A. Murray, *Apparatus medicaminum tam simplicium quam præparatorum et compositorum*. Göttingen 1794. Vol. 2, p. 399.

Jul. Fontenelle determined the specific gravity in 1824, also its solubility in water.¹⁾

Undoubtedly those who prepared mustard oil knew that the volatile oil does not preexist in the seed but is produced by the action of water. Yet the first to call attention to this fact were Glaser²⁾ in 1825, Boutron and Robiquet³⁾ in 1831, and independently of these Fauré⁴⁾ as well as Guibort,⁵⁾ both in 1831. Shortly after (1833), Dumas and Pelouze⁶⁾ made the first elementary analysis of the oil and discovered the thiosinamine, which mustard oil forms with ammonia. That mustard oil is produced by the action of a ferment was noticed by Boutron and Fremy.⁷⁾ They isolated myrosin by extracting the seed with alcohol and obtained mustard oil by allowing this substance to act on the aqueous extract of the seed which had previously been extracted with alcohol. Sinigrin or myronate of potassium, was first prepared by Bussy.⁸⁾ He termed the underlying acid *acide myronique* and with Robiquet⁹⁾ determined its physical constants and its behavior toward reagents. The knowledge of the chemical composition of the oil was advanced materially by Will¹⁰⁾ and simultaneously by Wertheim¹¹⁾ who regarded the mustard oil as allyl sulphocyanate.

Ludwig and Lange¹²⁾ confirmed the existence of sinigrin and its decomposition by ferment action into mustard oil, sugar and potassium acid sulphate. This reaction was made more clear by the detailed studies of Will and Körner.¹³⁾

¹⁾ Journ. de Chim. médicale 1 (1825), 130. — Trommsdorff's Neues Journ. der Pharm. 15, II. (1827), 210.

²⁾ Repert. f. d. Pharm. I. 22 (1825), 102.

³⁾ Journ. de Pharm. II. 17 (1831), 294. — Geiger's Magazin f. Pharm. und Exper. Kritik 36 (1831), 64 and 67.

⁴⁾ Journ. de Pharm. II. 17 (1831), 299 and 21 (1835), 464.

⁵⁾ *Ibidem* 17 (1831), 360.

⁶⁾ Ann. de Chim. et Phys. II. 53 (1833) 181. — Liebig's Annalen 10 (1834), 324.

⁷⁾ Journ. de Pharm. II. 26 (1840), 48 and 112. — Liebig's Annalen 34 (1840), 230.

⁸⁾ Journ. de Pharm. II. 26 (1840), 39. — Liebig's Annalen 34 (1840), 223.

⁹⁾ Journ. de Pharm. II. 26 (1840), 110.

¹⁰⁾ Liebig's Annalen 32 (1844), 1.

¹¹⁾ *Ibidem* 32 (1844), 54.

¹²⁾ Zeitschr. f. Chemie und Pharm. 3 (1860), 430, 577.

¹³⁾ Liebig's Annalen 125 (1863), 257.

Artificial mustard oil had been prepared by the action of allyl iodide on potassium sulphocyanate by Zinin¹⁾ and by Berthelot and de Luca.²⁾ The natural oil was therefore regarded as an ester of thiocyanic acid. Oeser,³⁾ however, showed that allyl thiocyanate and natural mustard oil possess different properties.

The true constitution of mustard oil as the ester of the isothiocyanic acid was recognized by Billeter⁴⁾ also by Gerlich.⁵⁾ They showed that by the interaction of allyl iodide and potassium sulphocyanate, allyl sulphocyanate is first formed and that upon heating this is converted into its isomer, the allyl isosulphocyanate.

As an explanation of this form of isomerism, A. W. Hofmann⁶⁾ had suggested that in the true thiocyanates the carbon is directly united with the sulphur, but in the isocompounds with the nitrogen.

Inasmuch as the possibility was not excluded that by the ferment action on sinigrin allyl sulphocyanate may first be formed, E. Schmidt⁷⁾ allowed this action to take place at low temperature. He ascertained that even at 0° allyl isosulphocyanate is formed and only traces of the normal isomer.

The last uncertainty in connection with the hydrolysis of sinigrin was removed by Gadamer.⁸⁾ He showed that the formula of sinigrin is $C_{10}H_{16}NS_2KO_8$ and not $C_{10}H_{16}NS_2KO_{10}$ as was supposed by Will and Kærner, also that the hydrolysis takes place by the addition of the elements of one molecule of water.

OIL OF STORAX.

Storax was known as a spice during antiquity and as such is mentioned by Herodotus,⁹⁾ Theophrastus¹⁰⁾ and Dioscorides.¹¹⁾

¹⁾ Journ. f. prakt. Chem. 64 (1855), 504. Liebig's Annalen 95 (1855), 128.

²⁾ Compt. rend. 41 (1855), 21.

³⁾ Liebig's Annalen 184 (1865), 7.

⁴⁾ Berl. Berichte 8 (1875), 464 and 820.

⁵⁾ *Ibidem* 650. — Liebig's Annalen 178 (1875), 89.

⁶⁾ Berl. Berichte 1 (1868), 28.

⁷⁾ *Ibidem* 10 (1877), 187.

⁸⁾ Arch. der Pharm. 235 (1897), 44.

⁹⁾ Herodoti *Historiarum libri*. Lib. 3, 97 and 107.

¹⁰⁾ Hehn, *Kulturpflanzen und Hausthiere in ihrem Uebergang aus Asien nach Griechenland und Italien*. Berlin 1877. p. 370.

¹¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 82; II, p. 375.

In mediaeval literature storax from several sources is mentioned. At times it was used medicinally.

The volatile oil of storax was distilled by Walter Ryff¹⁾ and Conrad Gesner.²⁾ Storax moistened with *aqua vitæ* (spirits) was distilled by Porta.³⁾

OIL OF AMERICAN STORAX.

Among the drugs from the new world, which received consideration in Europe after the discovery of America, there was an aromatic balsam derived from a tree named *Ocosotl* which was found in Mexico and Central America. In nearly all of its properties this balsam resembled the Levantine storax (*Styrax liquidus*) which had been known since antiquity. As in the case of the other American balsams (tolu, Peru, copaiba etc.) little was known about the botanical source and mode of production of this balsam. As a result balsams of different origin were frequently confounded.

The best descriptions of American storax are found in the 16. century treatises of Monardes,⁴⁾ Garcia da Orta⁵⁾ and Petrus Andr. Matthiolus.⁶⁾

¹⁾ Gualtherius Ryff, *New gross Destillirbuch*. 1556. fol. 176.

²⁾ Euxonymi Philatri *Ein köstlicher theurer Schatz*. 1555. Vol. 1, p. 176.

³⁾ Giov. Battista Porta *Magie naturalis libri viginti*. 1563. *Libri de destillatione*, p. 378.

⁴⁾ Monardes, *Historia medicinal de las cosas que se traen de nuestras Indias occidentales qui sirven en medicina*. Sevilla 1574. pp. 121 - 123. *Editio latina* Caroli Clusii. Antverpiæ 1539. p. 44.

⁵⁾ Garcias ab Horto, *Animatum et simplicium aliquot medicamentorum apud Indos nascentium historia. Deinde latino sermone in epitomen contracta . . . locupletioribus ab annotationibus illustrata a Carolo Clusio Atrobate. Quarta Editio, castigata et aliquot locis auctior*, Justus Bertramus. Antverpiæ 1593. - *Advehitur Hispalim, totius, non dicam Beticæ, sed etiam Hispaniæ celeberrimum emporium, olei quoddam genus ex America, suhrusi coloris, cujus mirabiles prædicant effectus in omnibus uteri morbis. Id oleum de Liquidambar nuncupant, ejus sane odoris fere, qui Styracis odorem æmuletur. Id vero ex eo liquore exprimitur, quem de Ocosotl arbore destillare Mexicana historia tradit in hunc modum: Inter arbores Mexicanas memoratur et Ocosotl arbor prægrandis et venusta, foliis hederæ similibus. Hujus liquor quem Liquidambar nuncupant, vulnera curat, atque cum cortice ipsius pollium permixtus, elegans odoratumque sullimentum præbet.*

⁶⁾ Petri Andreae Matthioli *Opera quæ extant omnia*. Veneti 1554. German edition. 1598. Lib. 1, fol. 90. "Zu den Styraxarten gehört auch ein

The first chemical investigation of American storax was carried out by Bonastre.¹⁾ Upon distillation of a relatively fresh balsam he obtained the high yield of 7 p. c. oil. Further investigations were made toward the end of the fifties by Wm. Procter,²⁾ and in 1874 by W. L. Harrison.³⁾

OIL OF ROSE.

Since the earliest periods the charm and fragrance of the rose have led to its appreciation and use. This is shown by the entire older literature, and of all the flower perfumes that from the rose has always received preference. In Chinese and Sanskrit writings the fragrance of the rose is much praised. Fats and oils saturated with the rose perfume have been used since earliest antiquity in perfumery and religious cults.⁴⁾ Thus Aphrodite anointed the dead body of Hector with rose oil.⁵⁾ The Greeks and Romans celebrated annually a rose festival, at which the graves of the dead were decorated with roses and their tombstones were anointed with rose oil.⁶⁾ Of the various flower cults that of the roses has been the most eminent since antiquity.⁷⁾

aus Neu-Spanien und Westindien kommendes flüssiges Harz, welches bei Einschnitten aus der Rinde großer Bäume mit ephenartigen Blättern ausfließt. Diese Bäume heißen "Ocosotl". Die Eingeborenen kauen die Rinde mit dem exsudierten Harze. Dieselbe ist angenehm wohlriechend und gibt beim Auspressen ein dickes, ebenso riechendes Öl, Oleum liquidambar."

¹⁾ Journ. de Pharm. II. 16 (1830), 88; *Ibidem* II. 17 (1831), 338. Trommsdorff's Neues Journ. de Pharm. 21, II. (1830), 242 and 24, II. (1832), 236.

²⁾ Americ. Journ. Pharm. 29 (1857), 261; *Ibidem* 38 (1866), 33. Proceed. Americ. pharm. Ass. 13 (1865), 160.

³⁾ Americ. Journ. Pharm. 46 (1874), 161-165. — Arch. der Pharm. 206 (1875), 541.

⁴⁾ Apparently the rose was not cultivated in Palestine. It is mentioned only a few times in the Bible. The "rose of Jericho," which is repeatedly mentioned, is the cruciferous *Anastatica hierochuntica*, L., a small plant growing in the desert which, upon drying, rolls up like a ball (Wisdom of Solomon, 2: 8. Song of Solomon, 2: 1. — Jesus Sirach, 24: 18; 50: 8. — Acts, 2: 8.)

⁵⁾ Homer's *Ilias*, chap. 23, V. 186.

⁶⁾ Friedländer, *Sittengeschichte der römischen Kaiserzeit*. 5th ed. 1881. p. 254.

⁷⁾ Ferd. Cohn, *Die Pflanze*. Breslau 1882. pp. 326-335. — Flückiger Pharm. Rundschau (New York) 12 (1894), 43, 91.

The earliest description of the method of preparation of the oil of rose of the ancients is found in the writings of Dioscorides.¹⁾ It was an aromatised fatty oil as were the majority of the rose oils of the middle ages, such as *Oleum rosarum*, *O. rosatum* or *O. rosaceum*, etc.

Aside from apocryphal Persian and other oriental traditions, the earliest definite directions for the preparation of roses and the use of the distillate are found in the writings of the Arabian historian Ibn Chaldun. He mentions that during the eighth and ninth centuries rose water was an important article of commerce, being carried as far as China and India.²⁾ In a codex of ceremonies of 946 by the East Roman emperor Constantine VII., Persian rosewater is mentioned as a toilet water.³⁾ At the beginning of the 10. century, Nonus Theophanes,⁴⁾ the physician to emperor Michael VIII., recommended and used rose water as a medicament. Avenzoar,⁵⁾ the physician to the calif Ebn Attafir of Morocco, who lived at the beginning of the 12. century; also his contemporaries Joannes Actuarius,⁶⁾ a physician of Constantinople, used rose water as an ophthalmic, and rose sugar as an internal remedy.

During this period, Persia seems to have supplied most of the rose water. During the fourteenth century it was also exported from Mesopotamia.⁷⁾ After the prime of the levant commerce, the Portuguese and Dutch were the principal carriers of goods between Aden, the ports of the Persian bay, India and the occident. Rose water constituted one of their

¹⁾ See p. 38. Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, pp. 56 and 123; Vol. 2, pp. 399-404.

²⁾ *Notices et extraits des manuscrits de la bibliothèque impériale à Paris*. Tom. 19 (1862), p. 364. — Istachri, *Das Buch der Länder*. Editio Mordmann. Hamburg 1754. p. 73.

³⁾ Constantinus Porphyrogenitus, *De ceremonibus antiquis byzant.* Editio Reiske. Lipsiæ 1751. Lib. II. cap. 15, p. 338.

⁴⁾ Nonus Theophanes. Editio Bernardi. *Præfatio ad Synesium: de febribus*. Amstelodami 1749. Cap. 28, p. 112.

⁵⁾ See p. 24.

⁶⁾ Actuarius, *De medicamentorum compositione*. Joanne Ruellio interprete. Basilæ 1540. pp. 18, 19, 22, 31.

⁷⁾ Voyage d'Ibn Batontah. 1854. Tom. 2, p. 140. Traduite par De-frémery.

principal articles of merchandise.¹⁾ During the 10. century the distillation of roses was introduced into Spain by the Arabs.²⁾

Throughout the middle ages, the distillation of rose water seems to have been an important industry of Persia. Unless strongly alcoholic wine was used in the process,³⁾ one would expect that in the distillation of large amounts of rose water⁴⁾ the separation of oil of rose at low temperatures in the form of a butyraceous mass had been noticed at an early date and probably used to perfume fats and fatty oils.

The first statement concerning rose oil, which possibly refers to the distilled oil, is found in the writings of Mesuë,⁵⁾ and in the almanac of Harib for the year 961, which mentions the time suitable for the preparation of rose water and a rose preserve.⁶⁾ In his *Compendium aromatariorum* written about the middle of the fifteenth century, Saladin of Asculi,⁷⁾ the body physician of a prince of Tarentum, describes the distillation of roses for the preparation of rose water and rose oil.

According to a statement by Langles,⁸⁾ distilled rose oil is twice definitely mentioned in Mohammed Achem's history of the great moguls of 1525 to 1667; also in the annals of the Mongolian empire written by Manucci,⁹⁾ a Venetian physician who lived 40 years in India.

¹⁾ Carl Ritter, *Erdkunde von Westasien*. Vol. 8, p. 745 and Vol. 9, p. 1010.

²⁾ *Calendrier rural d'Harib* in Duran de la Malle, *Climatologie comparée*. Paris 1849. p. 65. — Dozy, *Le Calendrier de Cordoue de l'année 961*. Leyden 1873.

³⁾ The above supposition is not supported by specific statements in literature. However, it seems reasonable since Persian rose water could be shipped without detriment to its quality to distant lands with tropical climate such as India, China and Egypt.

⁴⁾ See p. 64.

⁵⁾ See p. 24.

⁶⁾ Dozy, *le Calendrier de Cordoue de l'année 961*. Leyden 1873.

⁷⁾ Saladini Asculani *Compendium aromatariorum*. Venetii 1488. fol. 349.

⁸⁾ L. Langles, *Recherches sur la découverte de l'essence de roses*. Paris 1804.

⁹⁾ Manucci, *Histoire générale de l'Empire Monghol depuis sa formation jusqu'à présent*. Traduite par Catron. 2. edit. pp. 326- 327.

Unquestioned mention of the butyraceous oil of rose is made in 1574 by Hieronymus Rubeus,¹⁾ body physician to Pope Clements III.; also in the writings of Porta²⁾ of the year 1563 and again in 1604.

In the apothecary ordinances of Worms of 1582 and of Frankfurt-on-the-Main of 1587 *Oleum rosarum verum* is mentioned in the list of distilled oils.³⁾ About the same time Angelus Sala⁴⁾ describes the distillation of rose oil and characterizes it as *candiscente pinguidine, instar spermatis ceti*. In his Pharmacopœia of 1641, J. C. Schröder⁵⁾ enumerates the oil under the *Olea destillata usitatoria*.

Up to the 17. century and beyond Persia seems to have supplied the market with rose water and rose oil.⁶⁾ In the course of the century, however, the cultivation of the rose and the oil industry spread to India,⁷⁾ also westward, in its southerly course to Arabia, Tunis, Algiers, and Morocco and in its more northerly

¹⁾ Hieronymi Rubei *De destillatione liber, in quo stillatitiorum liquorum, qui ad medicinam faciuntur, methodus ac vires explicantur*. Ravennæ 1582. Sect. 2. Cap. 16, p. 102 and cap. 5, p. 132.

²⁾ Porta: *Magiæ naturalis libri viginti. De destillatione Libri*. Romæ 1563. Liber XX. *Omnium difficillime extractionis est rosarum oleum atque in minima quantitate, sed suavissimi odoris*.

³⁾ Flückiger, *Dokumente zur Geschichte der Pharmacie*. Halle 1876. pp. 37-41, 45, 47, 48, 49, 65.

⁴⁾ Angelus Sala, *Opera medico-chymica, quæ extant omnia*. Francofurti 1647. p. 63, 79.

⁵⁾ J. C. Schröder, *Pharmacopœia medico-physica*. Ulm 1649. Lib. II. Cap. 70, p. 241.

⁶⁾ Chardin, *Voyages en Perse*. Amsterdam 1711.. Vol. III, p. 178 and 349. Kämpfer, *Angebotatum exoticarum politico-physico medicarum fasciculæ quinque, quibus continentur variæ relationes, observationes et descriptiones rerum Persicarum et ulterius Asiæ, multa attentione, in peregrinationibus per universum Orientem, collectæ ab auctore*. Lemgoviz 1712. p. 373. - Olivier, *Voyage dans l'Empire Ottoman etc.* Paris 1807. Tom. 5, p. 367.

⁷⁾ Concerning the production of rose oil in India there are two reports written in 1782 by European scientists who lived at that time in Calcutta: the one under the title of "Asiatic Researches" in the Transactions of the Society instituted in Bengal etc., Calcutta 1788, vol. 1, paper 17; the other by Don Monro in the Transactions of the Society of Edinburg, vol. 2, Physical section. An abstract of the latter may be found in Tromsdorff's Journ. der Pharm. 1, II. (1794), 195.

course to Asia Minor, Turkey and Bulgaria.¹⁾ On the island of Chios also considerable rose oil was distilled at the beginning of the past century, which entered commerce via Smyrna.²⁾

The cultivation of roses in Bulgaria, which became of such importance in later years, was begun about the beginning of the 17. century. It seems to coincide approximately with the founding of Kezanlyk, a city on the southern slope of the Balkan mountains in East Roumelia.³⁾ It was not until the 19. century, however, that the rose industry of Bulgaria became a dangerous competitor of the Persian rose distillation. In recent years Bulgaria, in turn, has found successful competitors in Germany and France.

Since the 14. century, rose water and with it small quantities of rose oil, have been distilled for popular and medicinal use, also for perfumery, in the north European countries, especially in France, Germany and England. The amount of congealing oil obtained, however, was so small that rose oil was mostly bought from the orient and later from the Balkan states. The cultivation of roses for the purpose of distilling rose oil on a large scale was begun in France about the middle of this century, in Germany in 1883.⁴⁾

The high price of rose oil and the ease with which it can be adulterated seems to have brought about adulteration in Persia in the course of the 17. century. Engelbert Kämpfer⁵⁾ from Lemgo, who traveled in Persia in the years 1682 to 1684, mentions that rasped sandalwood is added for the sake of improvement to the roses in the process of distillation. This observation was verified in 1787 by Archibald Keir⁶⁾ in Chatra in the Ramgur, whereas Polier⁷⁾ observed in Cashmere during the same year

¹⁾ Forbes Watson, Catalogue of the Indian Department. Vienna Exhibition 1873, p. 94. — Douglas, Pharmaceutical Journ. III. 8 (1878), 811.

H. v. Schlagintweit in Buchner's Neues Repert. d. Pharm. 24 (1875), 129—143.

²⁾ Olivier, Voyage dans l'Empire Ottoman etc. Paris 1807. Tom. 5, p. 367.

³⁾ Kanitz, Donau-Bulgarien. Leipzig 1877—1879. Vol. 2, p. 111.

⁴⁾ Flückiger, Pharm. Rundschau (New York) 12 (1894), 92.

⁵⁾ Engelbert Kämpfer, *Amoenitatum exoticarum lasciculi* etc. Lemgo-viz 1712. p. 373.

⁶⁾ Archibald Keir, "Asiatic Researches" in Transactions of the Society instituted in Bengal, for inquiring into the history and antiquities, the arts, sciences and literature of Asia. Calcutta 1788. Vol. 1, p. 309.

⁷⁾ *Ibidem* Vol. 1, p. 332.

that in this country not sandalwood, but the fragrant Indian grass (*Andropogon*) is added to the roses for distillation.

Aside from its similar use during antiquity,¹⁾ the utilization of *Andropogon Schœnanthus*, L. for the purpose of adulteration of rose distillates, dates back more than a century. As a more convenient adulterant, palmarosa oil is more recently used in place of the grass from which it is distilled in India.

At an early period oil of rose was used as a perfume and, filled in fancy flasks, became a much sought for article in the bazaars of Constantinople, Smyrna, the levant and the entire orient. The demand being greater than the supply, both, manufacturers as well as dealers, early learned to increase the supply in a manner profitable to themselves. The former added palmarosa oil to the roses in the process of distillation, the latter still further diluted it with indifferent oils and spermaceti, the latter being necessary to maintain the proper congealing point.

OIL OF BITTER ALMONDS.

Almonds were known during antiquity. They are mentioned several times in the Old Testament,²⁾ also by Egyptian and by later Greek and Roman authors. Of the latter Theophrastus,³⁾ Dioscorides,⁴⁾ Scribonius Largus,⁵⁾ Pliny,⁶⁾ Palladius,⁷⁾ Celsus,⁸⁾ Alexander Trallianus,⁹⁾ Platearius¹⁰⁾ and others distinguished the

¹⁾ See p. 38.

²⁾ Genesis, 43:11. — Numbers, 17:8. — Ecclesiastes, 12:5. — Rosenmüller, *Handbuch der biblischen Altertumskunde*. Leipzig 1831. Vol. 4, p. 263.

³⁾ Theophrasti *Historia plantarum*. Lib. I, cap. 11, 18.

⁴⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. Vol. I, p. 155.

⁵⁾ Scribonii Largi *Compositiones medicamentorum*. Editio Helmreich. 1887. p. 8.

⁶⁾ Plinii *Naturalis historiae libri*. Lib. XVI, cap. 22; lib. XXXIII, cap. 75. Editio Littré. Vol. 2, p. 127.

⁷⁾ Palladii *De re rustica*, in Nisards *Les agronomes latins*. Paris 1877. p. 552.

⁸⁾ Celsi *De medicina libri VIII*. Editio Védérènes. *Traité de médecine*. de A. C. Celse. Paris 1876. p. 274.

⁹⁾ Alexandri Tralliani *Medici libri XII*. Editio Puschmann. Wien 1878. Vol. 2, p. 445.

¹⁰⁾ Platearii *Liber de simplice medicina*. "Circa instans." Editio Choulant.

bitter almond from the sweet. During the middle ages, both kinds of almonds were in use.

Bitter almond oil is first mentioned in the writings of Saladin¹⁾ in 1488 and those of Sancto Amando²⁾ in the 16. century. The distillates from bitter almonds and of other *Prunoideæ*, seem to have received but little attention during the period of general use of distilled waters. It is also uncertain whether the poisonous character of bitter almond oil was generally known. Even Scheele,³⁾ when he discovered hydrocyanic acid in 1782 does not seem to have fully realized its poisonous properties. He did not even recognize the similarity in odor between this acid and the distillates from the bitter almond and the cherry laurcl.

It was not until the eighties of the 18. century that bitter almond oil again received more attention. In spite of earlier observations,⁴⁾ it was not regarded decidedly poisonous until so pronounced in 1784 by Joh. Andr. Murray⁵⁾ of Göttingen. Following him, other contemporaries made the same statement.⁶⁾

The hydrocyanic acid content of bitter almond oil was first suspected in 1785 by the Erfurt apothecary Joh. Christ. Wil-

¹⁾ Saladini *Compendium aromatariorum*. Bononæ 1488. Index.

²⁾ *Expositio* Joannis de Sancto Amando *supra Antidotarium Nicolai incipit feliciter*. In the edition with Mesue's works. Veneti 1502. fol. 228, and *Additiones* fol. 85--87.

³⁾ Carl W. Scheele's *Physische und chemische Werke*. Translation by Hermstædt. Vol. 2, p. 331. — Flückiger, *Arch. der Pharm.* 224 (1886), 388. — *Pharm. Rundschau* (New York), 4 (1886), 211.

⁴⁾ According to the statement made by A. Wynter Blyth in his treatise on "Poisons", London 1895, the poisonous character of the peach and almond kernels was known to the Egyptians. — Mortimer in *Philosophical Transactions* (London) 87 (1731), 84 and 166. — Vater, *Dissertatio de laurocerasi indole venenata*. Wittenbergæ 1737. — Langrish, *Expériences de médecine sur des animaux*. Paris 1750. — Fontane, *Traité sur le venin de la vipère, le laurier cerise* etc. Florence 1781 and *Philosophical Transactions* (London) 70 (1781), 1. 210.

⁵⁾ J. A. Murray, *Apparatus medicaminum tam simplicium quam præparatorum et compositorum in praxeos adjumentum consideratus*. Göttingen 1784. Vol. 3, p. 215, 220 and 259.

⁶⁾ Hoyer, Crell's *Chem. Annalen*, *Beiträge* 1 (1793), 414, 415. — Gilbert's *Annal. der Physik. Neue Folge* 28, 220.

helm Reinder¹⁾ and in 1797 by Lucas²⁾ of Armstadt. Its presence, however, was not proven until 1803 when Bohm,³⁾ apothecary in Berlin, identified it. From that time on, bitter almond oil and its hydrocyanic acid content became the subjects of numerous investigations. Of these the reports of Schaub,⁴⁾ Schrader⁵⁾ and Ittner⁶⁾ advanced our knowledge, but a clear understanding of the formation and composition of the oil was gained only through those of Gay-Lussac,⁷⁾ Robiquet and Vogel,⁸⁾ Boutron-Charland⁹⁾ and finally those of Liebig and Wöhler,¹⁰⁾ and C. Winkler.¹¹⁾

The separation of the hydrocyanic acid from the benzaldehyde was first accomplished by Vogel in 1822 by treating the oil with baryta water. Liebig and Wöhler¹²⁾ introduced the method still in use involving ferrous sulphate, ferric chloride and milk of lime, which yielded pure benzaldehyde. Bertagnini¹³⁾ proposed sodium acid sulphite.

The separation of benzoic acid from bitter almond oil which has been exposed to the air was observed as early as 1823 by Stange¹⁴⁾ in Pégau.

¹⁾ Crell's Chem. Annalen 1785, II. 443. — Götting's Almanach für Scheidekünstler und Apotheker 8 (1787), 136.

²⁾ *Ibidem* 18 (1797), 101.

³⁾ Scherer's Allgem. Journ. der Chem. 10 (1803), 126. Gilbert's Annal. der Physik 13 (1803), 503.

⁴⁾ Schaub, *Dissertatio medico-chymica sistens Laurocerasi qualitates medicas ac venenatas etc.* Marpurgi 1802.

⁵⁾ Trommsdorff's Journ. der Pharm. 11, 1. (1803), 259 and 262.

⁶⁾ *Über das Vorkommen der Blausäure im Öle der bitteren Mandeln.* Schweigger's Journ. f. Chem. u. Phys. 24, 395. — F. v. Ittner, *Beiträge zur Geschichte der Blausäure, mit Versuchen über ihre Verbindungen und Wirkungen auf den tierischen Organismus.* Freiburg and Constanx 1809.

⁷⁾ Poggendorff's Annal. der Phys. Neue Folge 23 (1831), 1 and 138. — Schweigger's Journ. f. Chem. u. Phys. 16 (1831), 1.

⁸⁾ Journ. de Pharm. II. 8 (1822), 293. — Annal. de Chim. et Phys. 15 (1810), 29 and 21 (1822), 250. — Trommsdorff's Neues Journ. der Pharm. 7, 1. (1823), 217.

⁹⁾ Annal. de Chim. et Phys. 44 (1837), 352. — Liebig's Annalen 25 (1838), 175.

¹⁰⁾ Liebig's Annalen 22 (1837), 1.

¹¹⁾ Repert. f. d. Pharm. II. 17 (1839), 156. — Pharm. Zentralbl. 1839, 634.

¹²⁾ Liebig's Annalen 3 (1832), 252.

¹³⁾ *Ibidem* 85 (1853), 183.

¹⁴⁾ Repert. f. d. Pharm. I. 14 (1823), 329, 361 and 16 (1824), 80.

OIL OF CHERRY-LAUREL.

Cherry-laurel (*Prunus laurocerasus*, L.), appears to have become known in Europe toward the beginning of the 16. century. The aqueous distillate from the leaves has been used medicinally since the first half of the 18. century and its poisonous properties were repeatedly observed.¹⁾ The distilled oil is included in pharmacopœias since 1780.²⁾ The presence of hydrocyanic acid in the oil was observed simultaneously by Schaub³⁾ and by Schrader⁴⁾ at the beginning of 19. century.

OIL OF ROSE GERANIUM.

The pelargoniums which are indigenous to South Africa and which are now largely cultivated as decorative plants were introduced into Europe in 1690.⁵⁾ Recluz⁶⁾ of Lyon in 1819 first obtained a volatile oil⁷⁾ from the leaves. However, Demarson of Paris, in 1847 was the first to cultivate pelargoniums for the distillation of the oil. Since then their cultivation throughout France has been largely extended and was introduced into Algiers by Chiris and Monk.

In Spain pelargoniums were cultivated in the vicinity of Valencia by Robillard. Later they were also cultivated in the province of Almeria.

The island of Réunion has entered upon the cultivation of these plants since the eighties of the past century. Of much less importance are the plantations in Corsica.

¹⁾ Philosoph. Transact. (London) 87 (1731—1732), 84. - Abr. Vater, *Dissertatio de Laurocerasi indole venenata*. Wittenbergæ 1737. -- Bergius, *Materia medica*. Stockholm 1778, p. 401.

²⁾ J. A. Murray, *Apparatus medicaminum tam simplicium quam præparatorum et compositorum etc.* Göttingen 1784. Vol. 3, p. 213.

³⁾ D. Schaub, *Dissertatio medico-chymica, sistens Laurocerasi qualitates medicas ac venenatas etc.* Marpurgi 1802.

⁴⁾ Trommsdorff's Journ. der Pharm. 11, 1 (1803), 259 and 262.

⁵⁾ Piesse, *The Art of Perfumery*. IV. Edition, London 1879, p. 124.

⁶⁾ Pharmaceutical Journal I. 11 (1852), 325.

⁷⁾ This oil is not to be confounded with the so called Indian geranium oil, the palmarosa oil from *Andropogon Schœnanthus*, L.

OIL OF RUE.

Rue is mentioned in the Bible.¹⁾ As medicinal plant useful in the treatment of diseases of the eye, it is mentioned by Dioscorides,²⁾ Pliny, Columella³⁾ and Ovid.⁴⁾ For like purposes the plant was used during the middle ages.⁵⁾

The first mention of oil of rue (although possibly of the fatty oil) is found in Saladin's writings.⁶⁾ Gesner⁷⁾ distilled the oil about the middle of the 16. century. It is mentioned in the price ordinances of the cities of Berlin for the year 1574 and of Frankfurt for the year 1582, and in the *Dispensatorium Noricum* of the year 1589.

The yield of volatile oil from rue was first determined by Cartheuser⁸⁾ in the beginning of the 18. century. The oil was investigated by Caspar Neumann⁹⁾ and by G. S. P. Mähl¹⁰⁾ in Rostock in the year 1811, by Will¹¹⁾ in the year 1840, by Cahours¹²⁾ in 1845, by Gerhard¹³⁾ in 1848, by C. G. Williams¹⁴⁾ in 1858, by W. Hallwachs¹⁵⁾ in 1859, by C. Harbordt¹⁶⁾ in 1862, by Giesecke¹⁷⁾ in 1870, and by E. von Gorup-Besanez and Grimm¹⁸⁾ in 1871.

¹⁾ St. Luke, 11 : 42.

²⁾ Dioscoridis *De materia medica libri quinque*. Lib. III, cap. 45 and 52. — Editio Kühn-Sprengel. 1829. Vol. 1, p. 391.

³⁾ Columella, *De re rustica et de arboribus*. Lib. XII, 7.

⁴⁾ Ovidii *Remedia amoris*.

⁵⁾ Pfeiffer, *Zwei deutsche Arzneibücher aus d. 12. u. 13. Jahrh. Sitzungsberichte d. kais. Akad. der Wissensch. in Wien* 42 (1863), 137 and 142. (Haeser, *Geschichte d. Medizin*. 1875. Vol. 1, p. 663.) — Milton's *Paradise Lost*. XI. line 414:

"... then purg'd with Euphrasy and Rue
The visual nerve, for he had much to see."

⁶⁾ Saladini *Compendium aromatariorum*. Bononæ 1488. Index.

⁷⁾ Euonymi Philatri *Fin köstlicher Schatz*. 1555. Fol. 226.

⁸⁾ Joh. Friedr. Cartheuser, *Fundamenta materiae medicae*. Francof. ad Viadr. 1738. Vol. 2, p. 129.

⁹⁾ Casp. Neumann's *Medic. Chemie*. Ed. C. H. Kessel 1749. Vol. 2, p. 292.

¹⁰⁾ Trommsdorff's *Journ. der Pharm.* 20, II. (1811), 29.

¹¹⁾ Liebig's *Annalen* 35 (1840), 235.

¹²⁾ *Thèse présentée à la Faculté des sciences le 15. janv.* 1845. Compt. rend. 26 (1848), 262.

¹³⁾ Liebig's *Annalen* 67 (1848), 242.

¹⁴⁾ *Ibidem* 107 (1858), 374.

¹⁵⁾ *Ibidem* 113 (1860), 107.

¹⁶⁾ *Ibidem* 123 (1862), 293.

¹⁷⁾ *Zeitschr. für Chemie* 13 (1870), 428.

¹⁸⁾ Liebig's *Annalen* 137 (1871), 275.

OIL OF BUCHU LEAVES.

Buchu leaves indigenous to southern Africa appear to have long been used for medicinal purposes. In 1820 they were introduced into European commerce,¹⁾ having been brought from Cape Town to London. Since the later twenties of the past century they have been included in most pharmacopœias.

The volatile oil was first prepared by R. Brandes²⁾ in 1827.

THE OILS OF THE AGRUMEN FRUITS.

The genus *Citrus*, belonging to the subfamily *Aurantieæ* of the *Rutaceæ*, is indigenous to Central Asia. The large number of varieties of the citrus fruits, known by the collective term of agrumen fruits, is indicative of a very long period of cultivation. The citrus tree, having spread from southern China to Cochin-China and India,³⁾ became known to occidental peoples through the wars of Alexander the Great. Gradually its cultivation spread over Persia and Media to the westward.⁴⁾ Later, the Romans, and more particularly the Arabians, contributed to the spread of the citrus tree along the coast of the Mediterranean as far as Spain and Morocco. In the course of the crusades the tree and its fruit were spread among the peoples living to the north of the Mediterranean countries. Thus citrus culture has been spread over all countries with a warm or temperate climate so that at present the citrus tree is among the most cosmopolitan of all cultivated plants.

Whether the number of citrus species was limited during antiquity and whether the numerous varieties were gradually

¹⁾ R. Reece, Monthly Gazette of Health. London. Febr. 1821, p. 799.

²⁾ Arch. der Pharm. 22 (1827), 229.

³⁾ Bretschneider, On the study and value of Chinese botanical works with notes on the history of plants and geographical botany from Chinese sources. Foochow 1870, pp. 11 and 12. — E. Bonavia, The cultivated Oranges and Lemons of India and Ceylon with researches into their origin and the derivation of their names etc. London 1890.

⁴⁾ Brandis, Forest Flora of Northwestern and Central India. 1874, p. 50. — Hehn, Die Kulturpflanzen und Haustiere in ihrem Übergang aus Asien nach Griechenland und Italien. Berlin, 3rd ed. 1877. — Alphonse de Candolle, Origin of cultivated plants. 1885. p. 176.

developed with changed conditions in soil, climate and method of cultivation, does not become apparent from literature. The several names of the agrumen fruits appear to have passed from the Sanskrit to the languages of later peoples of antiquity. Thus the Greeks and Romans knew the lemon but not the orange, bergamot and limette.¹⁾ The lemon they named *Malum persicum*, *Malum citratum* or *citreum*. The supposition that the odor of the lemon, like that of the juniper and of the cedar (ζέδρος) of the Greek forests, kept away insects, caused the Greeks to apply this name to the "Persian" or "Median" apple, calling it *Malum cedreum*, *Malum citreum*. Hence developed the names *Citrus*, *Citrus nredica* and *Citrus persica*.²⁾

During the period from the 8. to the 10. centuries, the Arabians spread the cultivation of the bitter orange (*Citrus Bigaradia*, Risso) and of the lemon (*Citrus Limonum*, Risso) from Omân and Mesopotamia to Syria and Arabia. Thence the cultivation of these trees spread during the crusades along the coast of the Mediterranean to Spain and Morocco.³⁾ In Sicily the tree was cultivated as early as 1002.⁴⁾

The writings of the 12. to the 14. centuries frequently reveal the gradual spread of the agrumen fruits and the esteem in which they were held. Idrisi,⁵⁾ an Arabian geographer of the 12. century describes the lemon, in his travalogues of the African coast lands of the Mediterranean, but apparently did not find other

¹⁾ Scribonius Largus, *Compositiones medicamentorum*. Editio Helmreich. 1887. p. 65. Oribasius, *Medicinalia collecta*. Lib. I, cap. 64. Palladii *De re rustica*. In Nisard's *Les agronomes latins*. Paris 1877. p. 585.

²⁾ Theophrasti *Historia plantarum*. Editio Wimmer. Vol. 1, lib. IV. Dioscoridis *De materia medica libri quinque*. I. 166. - Virgilii *Georgica*. 2, 126:

Media fert tristis succos tardumque saporem

Felicitas inah: quo non presentius ullum,

Pocula si quando sævæ inlecece nocerecæ.

Hehn, *Kulturpflanzen und Haustierte in ihrem Uebergang aus Asien nach Griechenland und Italien*. Berlin 1877, p. 359.

³⁾ Ibn Baithar, *Heil- und Nahrungsmittel*. Translated by Sontheimer. 1842. Vol. 2, p. 452.

⁴⁾ Risso et Poiteau, *Histoire et culture des Orangers*. Edition Du Breuil. Paris 1872. Hehn, *Kulturpflanzen und Haustierte in ihrem Uebergang aus Asien nach Griechenland und Italien*. 1877, pp. 380-394. - Götze, *Beitrag zur Kenntnis der Orangengewächse*. Hamburg 1874, pp. 26-29.

⁵⁾ *Géographie d'Edrisi traduite par Amédée Jaubert*. 1836. Vol. 1, p. 162.

agrumen fruits, although such were cultivated in Spain at that time.¹⁾ Jacques de Vitri²⁾ who traveled through Palestine about 1225 found several varieties.

The sweet orange tree (*Citrus Aurantium*, Risso) was cultivated for decorative purposes in Nizza in 1336. In 1340 sweet oranges³⁾ (*Arancio*) were well known in Venice.⁴⁾ In 1369 *Arbores citronum* were cultivated in Genoa and along the Ligurian coast. Among the articles of export from Alexandria the lemon is mentioned in a treatise of 1420. In 1486 lemon trees were cultivated along the Riviera⁵⁾ and in 1494 in the Azores.⁶⁾ In 1546 the sweet orange was brought by the Portuguese Juan de Castro (viceroy of India from 1545 to 1548) from China to Portugal and cultivated there.⁷⁾ Although the sweet orange has been cultivated occasionally in northern Italy, its general culture in southern Europe appears to have spread from Portugal. The name *Portugallo* for oranges has maintained itself in Italy up to the present time. In 1516 Barbosa,⁸⁾ a Portuguese traveller mentions the lemons as fruits being introduced from the Malabar coast and Ceylon.

Into Germany the citrus fruits appear to have been introduced in the course of the 15. century. According to Conrad Gesner⁹⁾

¹⁾ Ibn-al-Acrām il Ishhīlīs during the second half of the 12. century wrote an agricultural treatise which was translated into French „*Livre d'Agriculture*“ edited by Clément Mullet. Paris 1864.

²⁾ *Limones, Citri et alia poma citrina . . . acidi seu pontici saporis quæ poma oranges ab indigenis nuncupantur.* Bongars, *Gesta Dei per Francos.* Hanoviae 1611, fol. 1099.

³⁾ For the etymology of the name orange see De Candolle, *Origin of the cultivated plants.* 1885. p. 184. — W. Roxburgh, *Flora Indica.* Vol. 2 (1839), p. 392.

⁴⁾ Cecchetti, *Archivio Veneto.* Vol. 30 (1885), p. 63.

⁵⁾ Gallesio, *Traité du Citrus.* Paris 1811, pp. 89, 103 and 321.

⁶⁾ Kunstmann, *D. Hieronymus Münzers Bericht über die Entdeckung der Guinea. Abhandlungen der histor. Klasse der bayerischen Akademie.* 1855, p. 362.

⁷⁾ Le Comte, *Nouveaux mémoires sur l'état de la Chine.* 2. Edition. Paris 1679. Tom. 1, p. 173. — Ferrari *Hesperides seu de malorum aureorum cultura et usu.* Romæ 1646, p. 425. — E. Bretschneider, *History of European botanical discoveries in China.* London 1898, Vol. 1, p. 6.

⁸⁾ *Libro di Odoardo Barbosa, in Ramusio Delle navigationi et viaggi.* Venetia 1554, fol. 347b. — Götze, *Beitrag zur Kenntnis der Orangengewächse.* Hamburg 1874, p. 24.

⁹⁾ Conrad Gesner, *De hortic Germaniæ liber recens.* Argentorati 1561. Lib. III.

they were cultivated during the middle of the 16. century for decorative purposes in hot houses and gardens.

Lemon juice, which is again being used for medicinal purposes in recent times, was esteemed as such by Roman physicians. Alexander Trallianus¹⁾ prescribed it during the middle of the 6. century. Lemon syrup was introduced as medicament by the Arabian physician Mesue through his *Antidotarium*.²⁾ The method for its preparation was included in his *Dispensatorium Noricum* of 1543 by Valerius Cordus.³⁾

The oil which is secreted in the cell tissues of the outer fruit rind of the agrumen fruits flows out when these oil cells are ruptured by pressure or friction. It is in this way that the oil is actually obtained. With the introduction and utilization of the agrumen trees, this oil must have been known at an early period, without, however, finding any application.

The earliest statements concerning distilled lemon and orange oils were made by Conrad Gessner⁴⁾ in 1555. Jaques Besson⁵⁾ followed in 1571, and Porta⁶⁾ in 1589. The latter described the preparation of the two oils by distillation of the fresh grated rinds. During the sixties of the 18. century Gaubius⁷⁾ recommended the same process.

The mechanical method of preparation of the agrumen oils by rupturing the oil cells of the fruit rinds by means of a grate was described by Cl. Joh. Geoffroy⁸⁾ in the beginning of the 18. century. In all probability, however, this method was practiced before this date.

The variety *Citrus Bergamia*, Risso, appears to be a cultural variety of much later date. The earliest information concerning oil of bergamot dates back as far only as the close of the 17. century. Thus e. g. it is mentioned in an inventory of an

¹⁾ Alexandri Tralliani medici libri XII græce et latine multo quam antea auctores et integriores etc. Basilie 1556. Editio Puschmann. Vienna 1878.

²⁾ See p. 24. — Gallesia, *Traité du Citrus*. Paris 1811. pp. 122, 247, 248.

³⁾ *Dispensatorium Noricum*. Editio 1548, pp. 179, 273.

⁴⁾ Euxonymi Philatri *Ein köstlicher, teurer Schatz* etc. Zürich 1555.

⁵⁾ Besson, *L'art et moyen parfait de tirer huyles et eaux de tous medicaments simples et oléagineux*. Paris 1571.

⁶⁾ Porta: *Magiæ naturalis libri viginti*. Romæ 1563. Edit. Napoli 1589. p. 188.

⁷⁾ H.D. Gaubii *Adversariorum varii argumenti liber unus*. Leidæ 1771. p. 31.

⁸⁾ *Mémoires de l'Académie des sciences de Paris*. 1721, 159.

apothecary shop of Giessen of 1688,²⁾ also in the treatise *Le parfumeur François, par le Sieur Barbe*, published in Lyon in 1693. In the latter the bergamot fruit is described as a pear, from the fruit rind of which the fragrant oil is obtained by trituration and expression. The further statement is made that the name bergamot is derived from the Turkish *Beg-âr mû di*, the "prince of pears". This statement would seem to indicate that the bergamot had its geographic source in the eastern coast lands of the Mediterranean. In his *Hesperides Norimbergensis* of 1713, the Nuernberg physician and botanist, I. G. Volkamer, described the *Limón bergamotta* as *gloria limonum et fructus inter omnes nobilissimus*.³⁾ He mentions that the Italians prepare an extremely fine essence from the fruit rind; that the name bergamot is in no way associated with Bergamo, a city in Lombardy; also that no agrumen varieties are cultivated in that region.

In some of the West Indian islands, agrumens have been cultivated since the beginning of the past century. Aside from the island Montserrat, they did not prosper, either because they did not receive proper care, or because the soil was not favorable. Proper care as well as soil they, however, found in the southern part of United States since about 1815. They are now being cultivated extensively in Florida, Louisiana, and, since the forties, in southern California.

In the municipal price ordinances concerning the wares of the apothecary and spices, oils of lemon and orange are enumerated among the distilled oils for the first time in that of Frankfurt-on-the-Main of 1582. Both oils had been introduced into the *Dispensatorium Noricum* of 1589 and into the *Pharmacopœia Augustana* of 1613. As indicated above, bergamot oil appears to have come into use in 1690.

In 1786 Remmler⁴⁾ tried to prepare rosin from oil of lemon. About the same time Liphard⁵⁾ mentions that the yield of lemon oil is larger when the fruit is allowed to stand until decay sets in.

In 1789 the apothecary Heyer⁶⁾ of Braunschweig, upon cooling bergamot oil, obtained crystals which he termed bergamot camphor.

²⁾ Flückiger, *Dokumente zur Geschichte der Pharmazie*. Halle 1876, p. 72.

³⁾ *Hesperides Norimbergenses*, 1713. *Liber III*, cap. 26, p. 156, b.

⁴⁾ Götting's *Taschenbuch für Scheidekünstler* 1786.

⁵⁾ Crell's *Chem. Annalen* 1787, II. 250.

⁶⁾ *Ibidem* 1789, I. 320.

OIL OF ORANGE FLOWERS.

Oil of orange flowers was known as early as the sixteenth century. Its distillation was described for the first time by Porta.¹⁾ About a century later, in the year 1680, it appears to have been made the fashionable perfume by the Duchess Flavio Orsini, Princess of Neroli, hence the name of essence of neroli.²⁾ On account of its delicate pleasant odor, the oil has been able to hold its reputation as one of the finest flower perfumes. This is also true of the distilled orange flower water, or *Aqua naphæ*,³⁾ which is used extensively for the aromatizing of food, confections and beverages, also for toilet purposes. The distillation of orange flower oil was described by Benatius⁴⁾ in 1806. The oil was investigated in 1825 by Bonastre⁵⁾ and in 1828 by Boullay.⁶⁾

OIL OF MYRRH.

The history of myrrh is inseparable from that of frankincense. Both come from the same countries. From early antiquity on, both have found like application in religious cults. In the commerce of the spices, both have played an important role. Hence myrrh and frankincense are almost invariably mentioned together in the oldest writings. As their geographic source, mythical Arabia and the coast lands along the south end of the Red Sea, the *Punt* or *Phun* of Egyptian documents, are

¹⁾ Jo. Batt. Porta, *Neapolitanæ Magnæ naturalis libri viginti etc.* Romæ 1563. fol. 118.

²⁾ Menagio, *Origini della lingua Italiana.* 1685. — *Dictionnaire de Trévoux.* — Paris 1771. Vol. 6, p. 178.

³⁾ The names *Naphé* and *Naphore* probably had their origin in Languedoc. (Risso and Poiteau, *Histoire naturelle des Orangers.* Paris 1818. Edition Du Breuil 1872. p. 211.) Orange flower water was distilled in the laboratories of German apothecary shops as early as the middle of the 17. century. (Simonis Paulli *Quadrupartitum botanicum de simplicium medicamentorum facultatibus etc.* Argentorati 1667. p. 385.)

⁴⁾ Berl. Jahrbuch der Pharm. 1806, 256.

⁵⁾ Journ. de Pharm. II. 11 (1825), 529.

⁶⁾ Journ. de Pharm. II. 14 (1828), 496. — Trommsdorff's Neues Journ. der Pharm. 10, 1. (1829), 226.

mentioned.¹⁾ As precious spices for burnt offerings, for the purpose of embalming and anointing,²⁾ both resins are frequently mentioned in Sanskrit writings, in the Vedas, in the Bible,³⁾ in the Koran, in the Papyrus Ebers and in the writings of Greek, Roman and Arabian authors. Moreover, they are frequently confounded with each other.⁴⁾

¹⁾ Agatharchides. In *Geographi Graeci minores. — De mari Erythraeo.* p. 87. — Arrianos, *Anabasis.* Lib. VII, 20 and 22. — Diodori *Bibliotheca historica.* Lib. 19, cap. 24. — Kosmas *Indopleustes, Topographia Christiana* in Migne's *Patrologiae cursus completus. Series Graeca.* 1860. Vol. 88, p. 374. — G. A. Hagenmacher, *Ergänzungsheft zu Petermanns Geographischen Mittheilungen.* 1876, 19. — I. M. Hildebrandt *Sitzungsberichte der Gesellschaft naturforschender Freunde zu Berlin.* 19. November 1878. p. 195.

K. Niebuhr, *Beschreibung von Arabien,* Copenhagen 1772. pp. 282 and 286. — H. Brugsch-Bey, *Geschichte Aegyptens unter den Pharaonen.* 1877. pp. 109, 110, 113, 281, 314. — Revoll, *Voyages au Cap des Aromates.* Paris 1880. pp. 136, 184, 227, 255, 259, 276, 283.

²⁾ For the preparation of the sacred oil, used according to Jewish ritual for the anointing of the high priests, the "pure myrrh" (Exodus 30:23) was prescribed. It was the exudation that flowed naturally (Song of Solomon, 5:5 and 13), hence it was also called tears or flowing myrrh (Stakte) (Exodus, 30:34). The wives of the Persian kings and the garbs of the kings were perfumed with myrrh. (Esther, 2:12. — Psalms, 45:9. Proverbs, 7:17). As a precious spice, myrrh was brought by the magi from the Orient to the new born King of the Jews (Matth, 2:11). Roman soldiers refreshed Christ, while on the cross, with wine and myrrh (Mark 15:23), and Nicodemus brought myrrh for the embalming of his body (John, 19:39).

³⁾ Exodus, 30:23; 37:25. — Psalms, 45:9. — Proverbs, 7:17. Song of Solomon, 1:13; 3:6; 4:14; and 5:5 and 13. — Mark, 15:23. Matthew, 2:11. — John, 19:39.

⁴⁾ Statements concerning the origin and history of myrrh and frankincense may be found in the following treatises: Papyrus Ebers of the University Library at Leipzig and of the Royal Library at Berlin. — Herodoti *Historiarum libri IX.* Lib. III. 107. — Theophrasti *Historia plantarum* Lib. IX, cap. 4. — Plutarchi *Moralia Isis et Osiris.* V. 383. — Diodori *Bibliotheca historica* Lib. V, cap. 41 and Lib. XIX, cap. 94. — Luciani *Opera, Drapetui* p. 1. Athenæi *Dipnosophistarum libri XV,* pp. 101 and 464. — Apulei *Metamorphoseon* Lib. 8 and 10. — Dioscoridis *De materia medica libri V.* Lib. I, cap. 24, 78 and 81. Editio Kühn-Sprengel 1829. Vol. I, p. 78. — Plinii *Naturalis historiae libri.* Lib. XII, 15, 16, 30 35 and Lib. XIV, 15. — Dümichen, *Geschichte des alten Aegyptens.* In Oncken's *Allgemeiner Weltgeschichte. Grapfal. d. Petam.* Vol. 2, pp. 12 34 — *Periplus maris Erythraei.* Lib. IX, cap. 4. — Vincent, *Commerce and Navigation of the Ancients in the Indian Ocean.* London 1807. Vol. 2, pp. 316 and 698. — Chishull, *Antiquitates asiaticæ.* London 1728, p. 71. D. Hanbury, *Science Papers* 1876. pp. 378—382. — Comp. also Sigismund, *Die Aromata.* Leipzig 1884. pp. 6—13.

OIL OF ORANGE FLOWERS.

Oil of orange flowers was known as early as the sixteenth century. Its distillation was described for the first time by Porta.¹⁾ About a century later, in the year 1680, it appears to have been made the fashionable perfume by the Duchess Flavio Orsini, Princess of Neroli, hence the name of essence of neroli.²⁾ On account of its delicate pleasant odor, the oil has been able to hold its reputation as one of the finest flower perfumes. This is also true of the distilled orange flower water, or *Aqua naphæ*,³⁾ which is used extensively for the aromatizing of food, confections and beverages, also for toilet purposes. The distillation of orange flower oil was described by Benatius⁴⁾ in 1806. The oil was investigated in 1825 by Bonastre⁵⁾ and in 1828 by Boullay.⁶⁾

OIL OF MYRRH.

The history of myrrh is inseparable from that of frankincense. Both come from the same countries. From early antiquity on, both have found like application in religious cults. In the commerce of the spices, both have played an important role. Hence myrrh and frankincense are almost invariably mentioned together in the oldest writings. As their geographic source, mythical Arabia and the coast lands along the south end of the Red Sea, the *Punt* or *Phun* of Egyptian documents, are

¹⁾ Jo. Batt. Porta, *Neapolitanæ Magnæ naturalis libri viginti etc.* Romæ 1563. fol. 118.

²⁾ Menagio, *Origini della lingua Italiana.* 1685. — *Dictionnaire de Trévoux.* — Paris 1771. Vol. 6, p. 178.

³⁾ The names *Naphé* and *Naphore* probably had their origin in Languedoc. (Risso and Poiteau, *Histoire naturelle des Orangers.* Paris 1818. Edition Du Breuil 1872. p. 211.) Orange flower water was distilled in the laboratories of German apothecary shops as early as the middle of the 17. century. (Simonis Paulli *Quadrupartitum botanicum de simplicium medicamentorum facultatibus etc.* Argentorati 1667. p. 385.)

⁴⁾ Berl. Jahrbuch der Pharm. 1806, 256.

⁵⁾ Journ. de Pharm. II. 11 (1825), 529.

⁶⁾ Journ. de Pharm. II. 14 (1828), 496. — Trommsdorff's Neues Journ. der Pharm. 10, 1. (1829), 226.

have been used earlier than myrrh. In addition to the literary sources mentioned under myrrh,¹⁾ the age of such uses is indicated by recent investigations.²⁾ Its most common application and largest use, frankincense found as incense in the religious cults of most of the peoples of antiquity. As such it was adopted by the Roman and Greek Catholic churches. Its use as incense, either by itself³⁾ or with myrrh⁴⁾ and other spices was especially esteemed in the temple service of the Hebrews, who obtained these spices through the Phœnicians.⁵⁾ Frankincense was also transported by caravan to Persia and Babylonia.⁶⁾ Indeed, the traffic in frankincense and myrrh exerted a great influence on the commerce of the coastlands of the Red Sea.

Among other writers Herodotus,⁷⁾ Plutarch,⁸⁾ Theophrastus,⁹⁾ and Athenæos,¹⁰⁾ later Strabo,¹¹⁾ Dioscorides¹²⁾ and Pliny,¹³⁾ also Arrian¹⁴⁾ make mention of the importance of frankincense.¹⁵⁾

¹⁾ See pp. 153 and 154.

²⁾ Cruttenden, in Transactions of the Bombay Geographical Society. Vol. 7 (1846), p. 121. -- Chishull, *Antiquitates Asiaticæ*. London 1728. pp. 65--72. -- Harris, The Highlands of Abyssinia. Description of the Frankincense tree in Guardafui. London 1844.

³⁾ Exodus, 30:34. Leviticus, 2:1, 2, 15, 16; 5:11; 6:15. 1. Chronicles, 10:29. Song of Solomon, 4:14. Isaiah, 43:23; 60:6. -- Jeremiah, 6:20. Matthew, 2:11.

⁴⁾ See p. 153, footnote 3 and 4.

⁵⁾ p. 6. Movers, *Das phœnische Alterthum*. 1856. Vol. 3, pp. 99 and 299.

⁶⁾ Sprenger, *Die alte Geographie Arabiens*. Bern 1875. pp. 212, 218, 219, 230, 264, 282, 284, 299, 308.

⁷⁾ Herodoti *Historiarum libri IX*. Editio Rawlinson. 1858. Vol. 2, p. 488.

⁸⁾ Flückiger, *Pharmakognosie*. 1891. p. 50.

⁹⁾ Theophrasti *Fresii Opera quæ supersunt omnia. Historia plantarum* Liber IV, cap. 4 and Liber IX, cap. 4. Editio Wimmer. Vol. 1, pp. 66 and 143.

¹⁰⁾ Athenæi *Dipnosophistarum libri XV*. pp. 253, 289 and 309.

¹¹⁾ Strabonis *Geographica*. Lib. XVI, cap. 4. Meyer, *Botanische Erläuterungen zu Strabo*. Königsberg 1852. pp. 137 139. -- Meyers *Geschichte der Botanik*. Königsberg 1855. Vol. 2, p. 88.

¹²⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. Vol. 1, p. 24.

¹³⁾ Plinii *Naturalis historiae libri*. Lib. XII, p. 41. Editio Littré. p. 489.

¹⁴⁾ *Periplus maris erythræi*. In Caroli Mülleri *Geographi Græci minores*. Paris 1855. Vol. 1, pp. 264-265.

¹⁵⁾ Hebrew *Lebonah*, Latin. *Thus* (from *thuss*, to sacrifice).

The distilled oil of frankincense was known to Valerius Cordus, but it is seldom mentioned in literature. In the treatises on distillation of the 16. century frankincense is mentioned as one of the many substances used in the distillation of the complex balsams *e. g.* by Gesner.¹⁾ Oil of frankincense is first found as *Oleum thuris* in the drug ordinances of the city of Berlin for 1574, and of Frankfurt-on-the-Main for 1587; further in the *Dispensatorium Noricum* of the year 1589.

The older investigations of frankincense as to content of volatile oil as well as the properties of the oil were mostly made in connection with like investigations of oil of myrrh of which the more important have been mentioned on p. 153.

Special observations concerning the oil and its constituents were made by Joh. E. Bætz²⁾ in 1787 and by Johnston³⁾ in 1839. The first investigation of the oil was made by Stenhouse⁴⁾ in 1840.

OIL OF ELEMI.

Statements supposed to pertain to elemi made during the period of the Romans are based largely on surmise.⁵⁾ In Europe, elemi became known in the course of the 15. century,⁶⁾ being used as an external remedy.⁷⁾ However, its use was anything but general and at the time of Valerius Cordus, little was known concerning the *resina elemnia*.⁸⁾ The regular introduction into Europe of Philippine elemi does not date back farther than about 1820.⁹⁾

¹⁾ Euxonymi Philatri *Ein köstlicher theurer Schatz*. 1555. p. 163.

²⁾ *Dissertatio*. Erlangæ 1787.

³⁾ *Philosoph. Transact.* London 1839, 301.

⁴⁾ Liebig's *Annalen* 35 (1840), 306.

⁵⁾ Flückiger, *Pharmakognosie*. 11. ed., p. 88. - Flückiger and Hanbury, *Pharmacographia*. p. 147.

⁶⁾ Monardes, *Historia medicinal de las cosas que se traen de nuestras Indias occidentales qui sirven en medicina*. Sevilla 1574. - Editio Clusii 1593, p. 315. - W. Piso, *Historia naturalis et medica occidentalis* 1658, p. 122. - Ray, *Historia plantarum* 1704. Vol. 3. Appendix p. 60 and 67.

B. Pomet, *Histoire des drogues*. Paris 1694. p. 261.

⁷⁾ Winkelmann, *Urkundenbuch der Universität Heidelberg* 1886, I. 125.

⁸⁾ Flückiger, *Dokumente zur Geschichte der Pharmazie*. 1876. p. 26. Flückiger, *Die Frankfurter Liste* 1872. p. 16.

⁹⁾ Valerii Cordii *Historia stirpium*. Lib. IV, cap. 97, p. 208.

¹⁰⁾ *Arch. der Pharm.* 17 (1826), 72.

Distilled oil of elemi is first mentioned in the price ordinance of Frankfurt-on-the-Main of 1587. It was admitted to the *Pharmacopœa Augustana* of 1613 and the Frankfurt Pharmacopœia of 1649.¹⁾

The first determination of the yield of oil was made by Caspar Neumann²⁾ about 1730. Redeterminations were made later by Manjeau³⁾ and Bonastre.⁴⁾

OIL OF SIGNALOES.

Fragrant woods from Mexico and French Guyana have been articles of commerce since the 18. century. They were named aloe wood because at first they were regarded as being identical with the older aloe wood.⁵⁾ Mexican lignaloes was first

¹⁾ Schröder, *Pharmacopœa medico-physica*. Ulm 1649. p. 194.

²⁾ Caspar Neumann, *Chymia medica dogmatico-experimentalis*. Editio Kessel. 1749. Vol. 2, p. 403–405.

³⁾ Journ. de Pharm. 10 (1824), 199.

⁴⁾ Journ. de Pharm. 9 (1823), 45–49. Trommsdorff's Neues Journ. der Pharm. 7, 1. (1823), 368.

⁵⁾ During antiquity the name aloe wood or *Adlerholz* was used as a collective term for fragrant woods obtained from different sources (Comp. J. Möller, *Lignum Aloes und Linaloeholz*. II. Mittell., Pharm. Post. 1898.) However, it appears to have been applied primarily to the resinous wood of *Aquilaria Agallocha*, Roxb. (N. O. *Thymeleaceæ*). Like sandalwood, it belongs to the spices used during antiquity. The East Indians called it *Ahalia* or *Ahaloth*, the Greeks ἀλόη also ἀγάλανος. The Arabians designated it *al-oed*, meaning the wood, also *agaluchin*. The latter word gave rise to the Portuguese designation *pao de aquila*, this in turn to the Latin *lignum aquilæ*. (Boorsma, *Ueber Aloeholz und andere Riechhölzer*. Bull. du Départ. de l'Agriculture aux Indes Néerlandaises. No. VII. [Pharmacologie III] Buitenzorg 1907, p. 1, footnote 4.) — Proverbs, 7: 17. In Luther's translation (Psalms, 45: 9. — Song of Solomon, 4: 14. — St. John, 19: 39, 8c.). In the English version it is translated as aloe wood. During antiquity it was prized so very highly that it was regarded as a most precious gift. From Egyptian documents from the 17. century B. C. it becomes apparent that signaloes, sandalwood and cassia were highly esteemed spices by the Egyptians and that these were imported via the Red Sea route. (Lieblein, *Handel und Schifffahrt auf dem Roten Meere in alten Zeiten*. Christiania 1886. p. 31). Not until the crusades did lignaloes enter the Mediterranean commerce. During the reign of the East Roman and later of the Greek emperors in Constantinople, and during the prime of the Levant commerce, signaloes was one of the common spices of the Orient. (W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 1, pp. 181, 191, 256, 418, 423; vol. 2, pp. 9, 153, 559.) About 1290

introduced into France in 1866. Guyana lignaloes was first brought to Marseille in the seventies and was there used for the distillation of the oil. In Cayenne the oil was first distilled in 1893.

CASCARILLA OIL.

It appears to have been in the first half of the 17. century that cascarilla bark was imported into Europe from the Bahama islands where the *Croton Elutaria*, Bennett is indigenous.¹⁾ The aborigines of these islands used the bark for fumigating purposes and as admixture to tobacco. Toward the end of the same century, cascarilla bark was used medicinally in Germany. In the pharmaceutical price ordinance of Minden of 1691, it is enumerated as *Cortex Chinæ de China nova*, and in that of 1694 as *Cortex Chinæ novæ seu Schacorillæ*.²⁾

Cascarilla oil is first mentioned in the *Taxa universalis*, Nuernberg 1747, as *Oleum Schaquerillæ*.³⁾ Statements concerning the yield and its specific gravity are made by Trommsdorff⁴⁾ in 1838.

OIL OF MASTIC.

During antiquity mastic was used for fumigation, embalming and as a taste corrective for wine. With other spices used for

Marco Polo found it to be one of the most precious perfumes used in China and India. (*Le livre de Marco Polo*, Edition Pauthier, Paris 1865, p. 532). Since the 16. century a lignaloes is brought into the market from CochinChina and Siam under the Malayan name *Kalambak*. It is obtained from the leguminous tree *Alocxylon Agallochum*, D. C. The wood of this tree resembles that of *Aquillaria Agallocha*, Roxb. and for a long time it was used medicinally and for perfume purposes under the name *Lignum aloes* or *Lignum agalli veri*. According to Möller the genuine lignaloes is odorless and hence contains no volatile oil. Hence the *oleum ligni aloes* of the spice ordinance of Ulm of 1596 (Reichard, *Beiträge zur Geschichte der Apotheken*, Ulm 1825, p. 208) must have been distilled from a different wood.

The wood of *Gonyxylus Miquelianus*, T. and B. (N. O. *Thymelacæ*) is likewise to be regarded as a genuine lignaloes. In European countries the *lignum aloes* is no longer in use. In British India, China and the Dutch archipelago it finds extended use even to-day. (Boorsma, l. c. p. 2.)

¹⁾ Flückiger and Hanbury, *Pharmacographia*, II. ed., p. 561.

²⁾ Flückiger, *Pharmakognosie*, III. ed., p. 612.

³⁾ G. Fendler, *Inaug. Dissertat.* Rostock 1900, p. 2.

⁴⁾ Trommsdorff's *Neues Journ. der Pharm.* 26, II. (1833), 136.

like purposes, it is frequently mentioned in literature.¹⁾ During the middle ages, mastic from Chios, Cyprus²⁾ and Samos³⁾ was one of the highly prized condiments. It was chewed and much used in the preparation of compound balsams. Hence it is referred to in Arabian medical treatises and later treatises on distillation as *Granomastice*.⁴⁾ Occasionally it is mentioned in connection with and at times confounded with frankincense as *Thus*.

Distilled oil of mastic, probably obtained by dry distillation, is first mentioned about the middle of the 15. century.⁵⁾ Such an empyreumatic oil of mastic is also mentioned in the inventory of the *Rathsapotheke* in Braunschweig of the year 1518.⁶⁾ Ryff⁷⁾ and Gesner⁸⁾ distilled mastic with wine. In the drug ordinances oil of mastic is first mentioned in that of Berlin of 1574, in books on medicine in the *Pharmacopœa Augustana* of 1480 and in the *Dispensatorium Noricum* of 1589. Later the oil went out of use almost altogether. Recently it is being used in Turkey for the preparation of a liquor.

GURJUN BALSAM OIL.

In India, gurjun balsam has been in use for a long time. The attention of Europeans was first directed to gurjun balsam

¹⁾ Esekial, 27:17. Herodoti *Historiarum libri*. Lib. IV, 177. — Theophrasti *Historia plantarum*, Lib. IX, cap. 1 and 4. — Plinii *Naturalis historiae libri*. Lib. XII, cap. 36. Editio Littré, vol. 1, p. 487. — Plutarchii *Moralia, Isis et Osiris*. Editio Parthey. 1850. p. 143 and 276. — Avicennæ *Libri in re medica omnes*. Venetiis. 1546. Lib. XI, cap. 462. — Palladii *De re rustica*. Editio Misard. 1877. p. 626.

²⁾ W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 2, p. 617.

³⁾ *Geographie d'Edrisi, traduite par Amédée Jaubert*. 1836. Vol. 2, p. 27. — Meyer, *Geschichte der Botanik*. 1856. Vol. 3, p. 299.

⁴⁾ Guérard, *Polyptique de l'abbé Irminon*. Paris 1844. Vol. 2, p. 336. — Pfeiffer, *Zwei deutsche Arzneibücher aus dem 12. und 13. Jahrhundert*. In *Sitzungsberichte der kaiserl. Akademie der Wissensch. zu Wien*. 42 (1863), 110—162. (Häser, *Geschichte der Medizin*. 1875. Vol. 3, p. 663.)

⁵⁾ Saladini *Compendium aromatariorum*. Venetiis 1488. Index.

⁶⁾ Flückiger, *Pharmakognosie*. 1891. p. 119.

⁷⁾ Gualtherus Ryff, *New gross Destillirbuch*. 1545. Fol. 181.

⁸⁾ Euonymi Philatri *Ein köstlicher theurer Schatz*. 1555. p. 237.

by Franklin¹⁾ in 1811 and by Wm. Ainslie²⁾ in 1813. Its source and method of preparation, however, were first described by Wm. Roxburgh³⁾ in 1827.

Its similar action to copaiba balsam was made known in India by the physician O'Shaughnessy⁴⁾ as early as 1812. It acquired a considerable reputation in India as a remedy against lepra, later also in England in dermatological⁵⁾ practice.

OIL OF LADANUM.

The ladanum resin, used since antiquity⁶⁾ as incense and embalming agent, is an exudation of the bush-like plants *Cistus creticus*, L., *C. ladaniferus*, L. and other species of the N. O. *Cistaceæ* indigenous to Asia Minor, Crete, Cyprus and a few other islands off the coast of Asia Minor. Up to the beginning of the 19. century it was an officinal drug, valued for its pleasant odor. It is often mentioned in literature⁷⁾ along with the ancient aromatics, storax, myrrh and frankincense. Not infrequently, especially in the translations of the Bible, it has been confounded with galbanum.⁸⁾ Lately it has gone almost completely out of use.

Ladanum oil, distilled at first with wine or spirits of wine (*aqua vitae*), was already known to Walter Ryff,⁹⁾ Conrad Gesner,¹⁰⁾

¹⁾ Franklin, Tracts on the dominions of Ava. London 1811. p. 26.

²⁾ Wm. Ainslie, *Nateria medica* of Hindoostan. Madras 1813. p. 186.

³⁾ Roxburgh, Plants of the coast of Coromandel. 1828. Vol. 3, p. 10 and plate 113.

⁴⁾ Bengal Dispensary, Calcutta. 1842. p. 22.

⁵⁾ Pharmaceutical Journ. III. 5 (1875), 729.

⁶⁾ Herodoti *Historiarum libri novem*. Lib. III, 107, 112.

⁷⁾ Plinii *Naturalis historię libri*. Lib. XII, cap. 37 and 44. — Dioscoridis *De materia medica libri quinque*. Lib. I, cap. 23. Edit. Kühn-Sprengel 1829. p. 120. — Douët d'Arcq, *Comptes de l'Argenterie des rois de France*. 1851, p. 19. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. vol. 2, p. 614. Schrader, *Monatsberichte der Berliner Akademie der Wissenschaften*, 1881, 413. — Thiselton Dyer, *Pharmaceutical Journ.* III. 15 (1884), 301 and 16 (1885), 386 and 779.

⁸⁾ W. Smith, *Dictionary of the Bible*. London. Vol. 2 (1863), p. 450. — Rosenmüller, *Handbuch der biblischen Altertumskunde*. Vol. 4 (1830), p. 156.

⁹⁾ Gualtheri Ryff, *New gross Destillirbuch*. 1545. fol. 179.

¹⁰⁾ Euonymi Philatri *Ein köstlicher theurer Schatz*. 1555. p. 237.

Hieronimus Rubeus,¹⁾ and to Porta.²⁾ It was taken up in medical books, first in the *Dispensatorium Noricum* of the year 1589 and in the *Pharmacopœa Augustana* of the year 1613.

CANELLA OIL.

When first introduced into Europe from the new world, canella bark, from *Canella alba*, Murray, was regarded as a kind of cinnamon bark. Later it was confounded with other barks, more particularly with Winter's bark, from *Drimys Winteri*, Forst. Canella bark was described as early as 1605 by Clusius³⁾ of Leyden. In 1690 Dale⁴⁾ called attention to its being mistaken for Winter's bark. In 1694 Pomet⁵⁾ confounded canella bark with that of *Cinnamodendron corticosum*, Miers⁶⁾ of St. Thomas. The latter was also repeatedly confounded with Winter's bark, even as late as the Paris Exposition of 1855.

In all probability canella oil was first distilled in 1707 by Sloane in England, later by Henry⁷⁾ in 1820. However, it appears to have found no application. It was examined by Meyer and von Reiche⁸⁾ in 1843, later by Bruun⁹⁾ and by Williams.¹⁰⁾

OIL OF CLOVES.

With cinnamon, nutmeg and pepper, cloves belong to the oldest known spices. As such they are mentioned in Chinese,

¹⁾ Hieronymi Rubi Ravennatis *De destillatione liber, in quo stillatitiorum liquorum, qui ad medicinam faciuntur, methodus ac vires explicantur*. Basilæ 1581. cap. 5, fol. 146.

²⁾ Porta: *Magiæ naturalis libri viginti*. 1564. p. 387.

³⁾ Caroli Clusii *Exoticorum libri decem*. Antverpiæ 1605. p. 78.

⁴⁾ Dale, *Pharmacologia seu manuductio ad Materiam medicam*. London 1693. p. 432.

⁵⁾ Pierre Pomet, *Histoire générale des Drogues*. Paris 1694. Tom. 1, p. 130.

⁶⁾ Annals and Magazine of Natural History, May 1858. — Miers, Contributions to Botany. Vol. 1, p. 121. — Grisebach, Flora of the British West Indian Islands. Vol. 1, p. 109.

⁷⁾ Trommsdorff's Taschenbuch f. Chemiker und Pharmazeuten 24 (1821), 101. — Berliner Jahrbuch d. Pharm. 24 (1821), I. 166.

⁸⁾ Liebig's Annalen 47 (1843), 224.

⁹⁾ Proceed. Wisc. Pharm. Assoc. 1898, 36.

¹⁰⁾ Pharm. Rundschau (New York) 12 (1894), 183.

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⁶⁾ Herodoti *Historiarum libri novem*. Lib. III, 107, 112.

⁷⁾ Plinii *Naturalis historię libri*. Lib. XII, cap. 37 and 44. — Dioscoridis *De materia medica libri quinque*. Lib. I, cap. 23. Edit. Kühn-Sprengel 1829. p. 120. — Douët d'Arcq, *Comptes de l'Argenterie des rois de France*. 1851, p. 19. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. vol. 2, p. 614. Schrader, *Monatsberichte der Berliner Akademie der Wissenschaften*, 1881, 413. — Thiselton Dyer, *Pharmaceutical Journ.* III. 15 (1884), 301 and 16 (1885), 386 and 779.

⁸⁾ W. Smith, *Dictionary of the Bible*. London. Vol. 2 (1863), p. 450. — Rosenmüller, *Handbuch der biblischen Altertumskunde*. Vol. 4 (1830), p. 156.

⁹⁾ Gualtheri Ryff, *New gross Destillirbuch*. 1545. fol. 179.

¹⁰⁾ Euonymi Philatri *Ein köstlicher theurer Schatz*. 1555. p. 237.

and those of Pigafetta,¹⁾ the companion of Magellan. Both described from their own observations not only the clovetree, but also the collection of the cloves, the former in 1504, the latter in 1521.

From the beginning of the 16. century to the close of the 17. century the commerce in cloves was almost exclusively in the hands of the Portuguese. Having crowded out the Portuguese, the Dutch in 1605 attempted to make a monopoly of the trade in cloves. With this end in view they destroyed the clove plantations in the Moluccas with the exception of those in the island of Amboina.²⁾

However in 1769 Poivre, the French governor of Bourbon and Mauritius, succeeded in transplanting clove and nutmeg trees from Amboina to his islands.³⁾ From here, in 1793, cultivated specimens were transplanted to French Guiana (Cayenne), Martinique, St. Vincent, Domingo and Trinidad; also about the same time to Zanzibar.⁴⁾

As ornamental plants, clove trees were introduced into Europe, more particularly into Venice, about the beginning of the 16. century.⁵⁾

On account of the high price of cloves, the aromatic stems remaining after the picking of the blossoms were introduced into commerce as early as the beginning of the 15. century.⁶⁾ However, they appear to have been used primarily for the

¹⁾ Ramusio, *Raccolta delle navigationi et viaggi*. Venetia 1554, fol. 404b. Edit. Hakluyt Society, London 1874, p. 134.

²⁾ Hasskarl, *Neuer Schlüssel zu Rumphs Herbarium amboinense*. 1866. Vol. 2, p. 17.

³⁾ Tessier, *Sur l'importation du giroflier des Moluques aux Isles de France, de Bourbon et de Sechelles, et de ces Isles à Cayenne. Observations sur la physique*. Paris. juillet 1779.

⁴⁾ Las Colonias espanolas, *Islas Filipinas*. Madrid 1880, pp. 72 and 122.

Guillain, *Documents sur l'histoire, la géographie et le commerce de l'Afrique orientale*. Paris 1856. Tom. 3, p. 318. - *Annales de Chim. et Phys.* I, 7 (1790), 1—21.

⁵⁾ Conrad Gesner, *Horti Germaniæ*. 1562. fol. 288.

⁶⁾ Pegolotti, *Della decima e delle altre gravanze imposte dal comune di Firenze*. 1766. Vol. 3, p. 98. — Luciano Banchi, *I porti della marenmma Senese durante la repubblica*. Archivio storico italiano. XII. parte 2 (1880), p. 90. — Bonaini, *Statuti inediti della città di Pisa*. Firenze 1857. Vol. 3, p. 106. — Henschel, *Janus*. Breslau 1846. Vol. 1, p. 40.

adulteration of clove powder.¹⁾ Nevertheless Porta in his writings about the middle of the 16. century, mentions that he had obtained an oil distilled from the stems.²⁾

Oil of cloves appears to have been distilled for the first time in the 15. century, but probably, like other aromatics, with wine or the addition of spirits of wine. This method of distillation was described by Walter Ryff,³⁾ Conrad Gesner,⁴⁾ Adam Lonicer⁵⁾ and others. Gesner also mentions the distillation of the oil, *per descensum*.⁶⁾ The pure oil however was, shortly afterwards distilled by Valerius Cordus,⁷⁾ by Winther of Andernach⁸⁾ and by Porta.⁹⁾ In the *Dispensatorium Noricum*, oil of cloves was admitted with a number of other oils in the edition of 1589. In drug ordinances it was first mentioned in that of the city of Berlin in 1574.¹⁰⁾

The yield of volatile oil from cloves was determined by Boerhaave,¹¹⁾ Fr. Holfmann,¹²⁾ Caspar Neumann¹³⁾ and H. Tromms-

¹⁾ Baader, *Nürnberger Polizeiverordnungen aus dem 13. bis 15. Jahrhundert*. 1861. pp. 19 and 139. Flückiger, *Zur älteren Geschichte der Pharmazie in Bern*. Schallhäusen 1862, p. 21.

²⁾ Baptista Porta: *Magiae naturalis libri viginti. Liber de destillatione*. Editio. Romae. 1608. p. 75.

³⁾ Gualtherus Ryff, *Neu gross Destillirbuch*. 1545. fol. 88.

⁴⁾ Luonymi Philatri *Ein künstlicher theurer Schatz*. Zürich 1553. pp. 227, 232. Editio 1557, p. 288.

⁵⁾ Adam Loniceri *Küchenerbuch und künstliche Conterfeyungen*. Editio Peter Uffenbach. 1551. p. 546.

⁶⁾ Luonymi Philatri *Ein künstlicher theurer Schatz*. Editio 1557. p. 288.

⁷⁾ Val. Cordus, *De articularis extractionibus liber*. Argentorati 1561. pag. 226.

⁸⁾ Güntheri Andernaci *Liber de veteri et nova medicina*. Basilae 1571. fol. 630- 635.

⁹⁾ Jo. Baptista Porta: *Magiae naturalis libri viginti. Liber de destillatione*. Antverpiae 1567. pp. 184 and 379.

¹⁰⁾ *Estimatio materiae medicae utriusque generis . . . in gratiam et usum publicum enitutum Marchiae Brandenburgensis. Autore Matthæo Flacco*. Berolini anno 1574.

¹¹⁾ Hermannus Boerhaave, *Elementa chemiae, quæ anniversario labore docuit in publicis privatisque scholis*. 1732. Vol. 2, p. 114.

¹²⁾ Frederici Hoffmanni *Observationum physico-chemicarum selectiorum*. 1722. Vol. 1, p. 11. *De caryophyllis aromaticis*. Halæ 1701.

¹³⁾ Caspar Neumann, *Chymia medica dogmatico-experimentalis*. Editio Kessel. 1749.

dorff.¹⁾ Boerhaave remarked that the variation in yield obtained on distillation was sometimes due to the adulteration with cloves which had been exhausted of their oil by distillation and then dried again.²⁾

Bonastre³⁾ in 1827 recognized the acid nature of clove oil and investigated the salt-like compounds of eugenol that were formed with alkalies. Ettling and Liebig⁴⁾ first showed that besides "*Nelkensäure*", eugenic acid, there is also present in the oil an indifferent body. Of the older investigations which were restricted mostly to eugenol, those of Dumas⁵⁾ (1833), Böckmann⁶⁾ (1838), Calvi⁷⁾ (1856), Brüning⁸⁾ (1857), Williams⁹⁾ (1858), Hlasiwetz and Grabowski¹⁰⁾ (1866) and Erlenmeyer¹¹⁾ (1866) may be mentioned.

OIL OF CAJEPUT.

Oil of cajeput appears not to have been brought to Europe until the beginning of the 17. century, when the Dutch took possession of the Moluccas. The first accurate account of the source of this oil was given by the missionary Valentyn,¹²⁾ and the merchant Georg Eberhard Rumpf of Hanau, both living in Amboina. The latter was an enthusiastic plant collector, and author of the first flora of the island Amboina.¹³⁾ According to

¹⁾ Trommsdorff's Journ. der Pharm. 23, II (1814), 23.

²⁾ Pfaff, *System der Materia medica*, 6 (1821), 433.

³⁾ Journ. de Pharm. II. 13 (1827), 464 and 513; Poggendorff's Annalen 10 (1827), 609 and 611.

⁴⁾ Liebig's Annalen 9 (1834), 68.

⁵⁾ Ann. de Chim. et de Phys. II. 53 (1833), 165. — Liebig's Annalen 9 (1834), 68.

⁶⁾ Liebig's Annalen 27 (1838), 155.

⁷⁾ *Ibidem* 99 (1856), 242.

⁸⁾ *Ibidem* 101 (1857), 202.

⁹⁾ *Ibidem* 107 (1858), 238.

¹⁰⁾ *Ibidem* 139 (1866), 95.

¹¹⁾ Zeitschr. f. Chemie 9 (1866), 95.

¹²⁾ *Verhandl. van der Geschiedenissen en Zaaken in Amboina*, Vol. 3, p. 193.

¹³⁾ G. E. Rumphii *Herbarium amboinense, plurimas complectens arbores lritices, herbas, plantas terrestres et aquaticas, quæ in Amboina et adjacentibus reperiuntur insulis* . . . (*Het Amboinsche Kruid boek*). It was not until forty years after the death of Rumpf that this work was published by Johann Burmann, Professor of Botany in Amsterdam. It appeared during the years 1741—1755 in six folios with 587 plates. The reference to cajeput oil will be found in vol. 2, p. 72.

Rumpf's¹⁾ statement, the Malays and Javanese were acquainted with oil of cajeput long before the Moluccas, the Banda and the Sunda islands were taken possession of, and used it as a diaphoretic. In Europe, the oil at first appears to have found no application. The first notice of such is by the physician J. M. Loehner in Nürnberg, and by the apothecary Joh. Heinr. Link in Leipzig. The former mentioned the oil in 1717,²⁾ the latter had bought the oil about the same time as a novelty from the physician of a ship which had just returned from the East Indies.³⁾ From this time on cajeput oil was used medicinally in Germany and was introduced into the apothecary shops⁴⁾ and mentioned in price ordinances and in medical works. For some time, however, it remained rare and expensive⁵⁾ and not until 1730 did larger quantities of the oil come into the European market via Amsterdam.⁶⁾ In Germany, it was at first called *Oleum Wittnebianum* after a merchant E. H. Wittneben of Wolfenbüttel, who had lived several years in Batavia, and who, in German essays,⁷⁾ had recommended the oil as a valuable remedial agent.

In France and in England oil of cajeput was not used until the beginning of the past century.

The first detailed account of the simple methods of distillation of cajeput oil used on the Moluccas, was given by the French traveler Labillardière,⁸⁾ who had visited the island of Buru in 1792. The use of copper stills and condensers gave rise to a green

¹⁾ Rumphii *Herbarum amboinense* Vol. 2, chapt. 26.

²⁾ *Academia Natural. Curiosor. Ephemerides Centuri V, VI.* Nürnberg 1717. p. 157.

³⁾ *Sammlung von Natur und Medizin, wie auch von Kunst- und Literatursgeschichten.* Leipzig and Budissin. 1719 p. 257.

⁴⁾ Mückiger, *Dokumente zur Geschichte der Pharmazie.* 1876. pp. 88 and 90.

⁵⁾ Abraham Vater, *Catalogus variorum exoticorum rarissimorum.* Wittenbergæ 1726.

⁶⁾ Schendus van der Beck, *De India rarioribus.* *Acta natural. Curiosor.* Vol. 1. Appendix 1725. p. 123.

⁷⁾ This designation was largely due to an erroneous statement in the *Commercium litterarium* published by I. C. Götz in 1731 in Nürnberg. In it Wittneben is mentioned as discoverer of the oil of cajeput. This misstatement was not corrected until twenty years later in the dissertation of Martini, p. 178, footnote 4.

⁸⁾ *Travels in the East Indian Archipelago.* London 1868. p. 282.

color due to a small amount of copper in the oil. The cause of this coloration was first detected by the apothecaries Hellwig¹⁾ in Stralsund in 1786, Joh. Friedr. Westrumb²⁾ in Hameln in 1788, and Trommsdorff³⁾ in Erfurt in 1795.⁴⁾

EUCALYPTUS OIL.

The oil of *Eucalyptus piperita*, Sm., is the oldest oil of eucalyptus leaves, being mentioned as early as 1790.⁵⁾ In 1853 the botanist Ferdinand von Müller recommended to the Province of Victoria the distillation of the leaves of the eucalyptus species.⁶⁾ Bosisto,⁷⁾ who had distilled experimentally the dried leaves in London, established in 1854 the first factory in Australia,⁸⁾ and is, therefore, to be considered as the founder of this extensive industry.

Australian eucalyptus oil came into the German market about 1866 without any botanical reference as to its source. Probably it was principally the distillate from *Eucalyptus amygdalina*.

Eucalyptus Globulus was discovered in Tasmania in 1792 by Labillardière and introduced into Europe in 1856 by Ramel.⁹⁾ The oil of this species was obtained on a large scale, first in southern France, Algiers and California, and has become a staple article of commerce only since the early eighties of the past century.

¹⁾ Crell's Chem. Annalen 1786, II. 141.

²⁾ Joh. F. Westrumb, *Kleine physikalisch-chemische Abhandlungen*. Leipzig 1788. Vol. 2, No. 1.

³⁾ Trommsdorff's Journ. der Pharm. 2, 1. (1795), 115.

⁴⁾ Earlier contributions on cajuput oil are: D. Martini, *Dissertatio epistularis, qua de oleo Wittnebianum seu Kajeput ejusque saluberrimis effectibus exponit*. Guelpherb. 1751. -- Joh. Fr. Cartheuser, *De oleo cajeputi. Dissertatio physico-chemica*. Erfurt 1754.

⁵⁾ Journal of a Voyage to New South Wales by John White. Surgeon-General to the Settlement, published 1790.

⁶⁾ Ferd. v. Müller, *Eucalyptographia*. Melbourne 1879. -- Ferd. v. Müller, *Select Extra-Tropical Plants*. IX. Edit. Melbourne 1895. p. 184.

⁷⁾ Bosisto, *Transact. Royal Soc. Victoria* 1861 64.

⁸⁾ Bericht von Schimmel & Co. October 1896, 13.

⁹⁾ Bentley, On the characters, properties and uses of *Eucalyptus Globulus*. London 1854. Sawyer, *Odorographia*. London 1894. Vol. 2, p. 241.

OIL OF CORIANDER.

The coriander plant, *Coriandrum sativum*, L., cultivated in many countries and in nearly all climates, was used as a kitchen spice even before the Christian Era.¹⁾ As such, coriander fruit is mentioned repeatedly in Sanscrit writings, in the Bible²⁾ and in later Roman writings.³⁾ Together with other offerings,⁴⁾ coriander fruit has also been found in old Egyptian monuments of the 10. century B. C.

Coriander is also mentioned among the useful plants recommended for cultivation by Charlemagne,⁵⁾ but it appears to have received, as with the Arabians so also with the Germans in the middle ages, only slight consideration. The fruit is again mentioned in the medical⁶⁾ and distilling books of the 16. century, although it had been employed now and again as a kitchen spice.⁷⁾

The distilled oil of coriander appears to have been first obtained by Porta⁸⁾ in the 16. century who prepared it after moistening the fruit with *aqua vitae*. In the price ordinances of spices, the oil is first included in that of Berlin of 1574 and that of Frankfurt-on-the-Main of 1587; also in the 1589 edition of the *Dispensatorium Noricum*.

Coriander oil was investigated in 1785 by Hasse,⁹⁾ in 1835

¹⁾ Prosper Alpinus, *De plantis Aegypti liber*. Venetii 1591. Cap. 42, p. 61.

²⁾ Exodus, 16:31. Numbers 11:7.

³⁾ Theophrasti *Opera quae supersunt omnia. Historia plantarum*. Lib. VI. 4. Editio Wimmer. 1866, p. 117. - Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829, p. 410. Plinii *Naturalis historiae*. Lib. XIX. 35 and XX. 82. Editio Littré. Vol. 1, p. 729 and Vol. 2, p. 33. Catonis *De re rustica* Libri XII. Cap. 119 and 157, Edit. Nisard, p. 34 and 54. - Columellae *De re rustica*. Cap. 10 and 11. Edit. Nisard, pp. 414, 442. Palladii *De re rustica*. Lib. III. 24. Lib. IV. 9. Editio Nisard, p. 567 and 583.

⁴⁾ G. Schweinfurth, in the *Berichte der deutsch. botan. Gesellschaft*, 2 (1884), 359.

⁵⁾ See footnote 8, p. 133.

⁶⁾ K. Regel, *Das mittelhochdeutsche Gothaer Arzneibuch*. 1873. p. 13.

⁷⁾ Hirsch, *Danzigs Handels- und Gewerbe-Geschichte*. Leipzig 1858. p. 243.

⁸⁾ Jo. Bapt. Porta *Magiae naturalis libri viginti*. Lib. X. "De destillatione." Romae 1608, p. 379.

⁹⁾ Crell's *Chemische Annalen* 1785, I. 422.

by Trommsdorff,¹⁾ in 1852 by A. Kawalier²⁾ and in 1881 by B. Grosser.³⁾ A true insight into its composition, however, was brought about by the investigations of Semmler (1891) and of Harbier (1893).

OIL OF CUMIN.

During antiquity both the Roman or mother caraway of the Orient, *Cuminum Cyminum*, L., and the common caraway were used as spices. In literature, e.g. in the translations of the Bible, both have been confused, not only the one with the other, but both with the seeds of the black caraway, the *Nigella*.⁴⁾ According to statements in the Papyrus Ebers, cumin and caraway seeds have been found in Egyptian graves. Dioscorides⁵⁾ describes both. In Spain both cumin and caraway were cultivated by the Arabians during the 12. century.⁶⁾ Both are enumerated in the market ordinances of Brugge in Flandria of 1307,⁷⁾ and of Danzig in the beginning of the 15. century.⁸⁾ In 716 cumin seed is mentioned among the objects of tribute to be paid to the Norman monastery Corbie.⁹⁾ During the early part of the 13. century, Edrisi, the geographer, mentions both fruits as products of Morocco and Algiers.¹⁰⁾ Both were used in England toward the beginning of the 13. century,¹¹⁾ and in Germany in the 15. century.¹²⁾

¹⁾ Arch. der Pharm. 52 (1835), 114.

²⁾ Liebig's Annalen 84 (1852), 351; Journ. f. prakt. Chem. 54 (1853), 226.

³⁾ Berl. Berichte 14 (1881), 2485.

⁴⁾ Isaiah, 28:25 to 27. — Rosenmüller, *Handbuch der biblischen Altertumskunde*. Leipzig 1830. Vol. 4, p. 100. — Plinii *Naturalis historiae libri*. Lib. XIX, cap. 8.

⁵⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel 1829. Vol. 1, 407.

⁶⁾ Ibn-al-Awam, *Livre d'agriculture, traduit par Clément-Mullet*. 1864. Vol. 2, p. 242 and 244.

⁷⁾ Warnkönig, *Histoire de la Flandre*. 1836. Vol. 2, p. 512 and vol. 4, p. 449.

⁸⁾ Hirsch, *Danzigs Handels- und Gewerbegeschichte*. Leipzig 1858, p. 243.

⁹⁾ Pardessus, *Diplomata, Chartæ*, etc. Paris 1849, p. 307.

¹⁰⁾ Edrisi, *Description de l'Afrique et de l'Espagne, traduit par Dozy et De Goeje*. Leyden 1866. pp. 75, 97, 150.

¹¹⁾ Rogers, *History of Agriculture and Prices in England*. 1876. Vol. 1, p. 631 and vol. 2, pp. 543—547. Riley, *Monumenta Guildhalli Londoniensis*. 1859. p. 224.

¹²⁾ Thomas, *Fontego dei Tedeschi in Venezia*. 1874. p. 252.

The volatile oil of cumin is included in the price ordinances of Berlin of 1574, and of Frankfurt of 1582, also in the 1589 edition of the *Dispensatorium Noricum*.

OIL OF CELERY SEED.

Celery was known at the beginning of the Christian era.¹⁾ As a kitchen spice it is recommended in the *Capitulare* of Charlemagne 812,²⁾ as a medicament by the abbess Hildegard³⁾ in the early part of the 12. century.

During the period of the distilled waters, celery water was used as a domestic remedy and is repeatedly described in the treatises on distillation of the 15. and 16. centuries.⁴⁾

Distilled oil of celery appears to have come into use during the middle of the 16. century. In the spice and drug ordinances it is first mentioned in that of Frankfurt-on-the-Main of 1587, also in the 1589 edition of the *Dispensatorium Noricum*.

The apiol which crystallizes from the oil at lower temperatures was observed as early as 1715 by the apothecary Christian Link⁵⁾ of Leipzig, again in 1745 by A. Fr. Walther.⁶⁾

The oils from the fresh herb and seeds was distilled by Pabitzky⁷⁾ in 1754. Both the oils and the crystals separating therefrom are further mentioned by Dehne,⁸⁾ Bolle,⁹⁾ and

¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 413. — Plinii *Naturalis historiae libri*. Lib. XX, cap. 47. Editio Littré. Vol. 2, p. 18. Apicius Caelius in Meyer's *Geschichte der Botanik*. Vol. 2, p. 242. — Dierbach, *Flora Apiciana*. 1831. p. 52.

²⁾ *Capitulare de villis et cortis imperialibus*. Anno 812. Comments by A. Thier in Fülling's *Landwirtschaftliche Zeitung*. Berlin 1878. 241—260.

³⁾ Hildegardis *Abbatissæ Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne. *Patrologiæ cursus completus*. Paris 1855. p. 1158.

⁴⁾ Hieronymus Brunschwig, *Liber de arte destillandi*. 1500. fol. 87.

⁵⁾ *Sammlung von Natur und Medicin, wie auch von Kunst- und Literaturgeschichten*. Leipzig and Budissin 1716.

⁶⁾ A. Fr. Walther, *De oleis vegetabilium essentialibus*. *Dissertatio*. Leipzig 1745. p. 17.

⁷⁾ Braunschweiger Anzeiger 1754, 1205.

⁸⁾ Crell's Chem. Journ. 1778, I. 40.

⁹⁾ Arch. der Pharm. 29 (1829), 168.

Bley.¹⁾ The first elementary analysis of the "celery camphor" was made by Blanchet and Sell.²⁾ It was further investigated by Lœwig and Weidmann.³⁾

OIL OF CARAWAY.

Like other related umbelliferous plants, caraway or *Carum Carvi*, L., has been cultivated in Europe and Asia since antiquity and used as a kitchen spice.⁴⁾ With these other umbelliferous plants, and at times confounded with the one or the other, it is frequently mentioned in ancient literature,⁵⁾ also in mediæval medical books and in the treatises on distillation. During the beginning of the 12. century caraway was cultivated by the Arahians in Morocco⁶⁾ and Spain.⁷⁾ About the same time caraway was praised as a medical agent by the abbess Hildegard.⁸⁾ As such it was introduced into the German medical treatises of the 12. and 13. centuries.⁹⁾ In England caraway was cultivated during the 13. century and used as a kitchen spice.¹⁰⁾

¹⁾ Trommsdorff's Neues Journ. der Pharm. 14, II. (1827), 134.

²⁾ Liebig's Annalen 6 (1833), 301.

³⁾ Liebig's Annalen 32 (1839), 283.

⁴⁾ See also oil of cumin on p. 169. Plinii *Naturalis historiae libri*. Lib. XIX, cap. 8. *Condimentorum omnium stomachi fastidiis cuminum amissimum*.

⁵⁾ Isaiab, 28:25 and 27. — Matth., 23:23. — Dioscoridis, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 406. — Plinii *Naturalis historiae libri*. Lib. XIX, 49. Editio Littré. Vol. 1, p. 736. Palladii *De re rustica*. Lib. XII, p. 51. — Editio Misard, *Les agronomes latins*. Paris 1877. p. 486.

⁶⁾ Edrisi, *Description de l'Afrique et de l'Espagne. Texte arabe avec une traduction*, par Dozy and De Goeje. Leyden 1866. pp. 75, 97, 150.

⁷⁾ Ibn-el-Baitar, *Djāmi el-mutrūdāt*. Translated by Sontheimer. 1840. Vol. 2, p. 368. — Leclerc's translation. Vol. 3, pp. 164, 197, 198. Ibn-al-Awam, *Livre d'agriculture*. Translated by Clément-Mullet. 1864. Vol. 2, pp. 242 and 244.

⁸⁾ Hildegardis *Abbatissæ Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne. 1855. p. 1158.

⁹⁾ Pfeiffer, *Zwei deutsche Arzneibücher aus dem 12. und 13. Jahrhundert. Sitzungsberichte der kais. Akad. der Wissenschaften in Wien*. 1863. p. 14. (Häser, *Geschichte der Medizin*. 1875. Vol. 1, p. 663.)

¹⁰⁾ Meddygon Myddlai. Published at Llandovery. 1861. pp. 158, 354. — Rogers, *History of Agriculture and Prices in England*. 1876. Vol. 1, p. 631 and Vol. 2, p. 543–547.

In municipal spice ordinances, caraway is first mentioned in that of Brugge¹⁾ of 1304. It is also enumerated in that of Danzig²⁾ of the middle of the 15. century.

Distilled oil of caraway is first mentioned in the price ordinance of Berlin of 1574, and that of Frankfurt of 1589, also in the 1589 edition of the *Dispensatorium Noricum*.

OIL OF AJOWAN.

Apparently ajowan³⁾ was first brought to Europe in 1549.⁴⁾ In 1693 it was used for medical purposes in London.⁵⁾ In 1773 it is mentioned by Percival⁶⁾ of England.

OIL OF ANISE.

Anise is one of the spice plants known to, and used during, antiquity. It is mentioned in the Vedas and in the Bible.⁷⁾ The cultivation of anise in Egypt and in the Island of Crete is recorded in the writings of Dioscorides, Columella and Pliny;⁸⁾ its medicinal use in those of Scribonius Largus, Marcellus Empiricus, and Alexander Trallianus. In the 4. century Palladius⁹⁾ gave directions for its cultivation. In 970 Asia Minor and the mediterranean countries¹⁰⁾ supplied anise, during the 12. century Spain also.¹¹⁾ Through his *Capitulare* of 812 Charlemagne stimulated

¹⁾ Warnkönig, *Histoire de la Flandre*. 1836. Vol. 2, p. 512 and vol. 4, p. 449.

²⁾ Hirsch, *Danzigs Handels- und Gewerbsgeschichte*. Leipzig 1858. p. 243.

³⁾ Flückiger and Hanbury, *Pharmacographia*. London 1879. p. 303.

⁴⁾ Anguillara, *Semplici Vinegia*. 1561. p. 130.

⁵⁾ S. Dale, *Pharmacologia seu manu ductio ad Materiam medicam*. London 1693. p. 211.

⁶⁾ Essays, Medical and Experimental II. (1773), p. 226.

⁷⁾ Matth., 23:23. In the English version the original is translated as anise, whereas Luther translates it with dill. Comp. p. 180, footnote 2.

⁸⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 405. Columellæ *De re rustica* in Nisard's *Les agronomes latins*. Paris 1877. Plinii *Naturalis historie libri*. Lib. XX, 72—73.

⁹⁾ Palladii *De re rustica libri XIV*. Lib. III, 14 and lib. IV, 9. In Nisard's *Les agronomes latins*. Paris 1877. pp. 569 and 583.

¹⁰⁾ *Codex Vindobonensis, sive Abn Mansur Mowaffi (Atherri) Heratensis liber fundamentarum Pharmacologie*. Editio F. R. Seligmann. Wien 1859. p. 21.

¹¹⁾ Ibn-al-Awain, *Livre d'agriculture*, translated by Clément-Mullet. 1864. Vol. 2, p. 249.

the cultivation of anise north of the Alps.¹⁾ In 1305 anise is enumerated among the dutiable spices in London,²⁾ and toward the beginning of the 16. century anise and fennel were cultivated in England.³⁾

On account of its property to solidify, distilled oil of anise has, no doubt, been noticed as long as anise has been used for the preparation of anise water. The distillation of the oil was, however, first described in the works of Hieronymus Brunschwig,⁴⁾ Ad. Lonicer,⁵⁾ Walter Ryff,⁶⁾ Conrad Gesner,⁷⁾ Hieronymus Rubcus⁸⁾ and Porta.⁹⁾ Valerius Cordus¹⁰⁾ in 1540 called attention to the ready solidification of the oil. Nearly a century later Robert Boyle again described the "butter-like" solidification of anise oil.¹¹⁾

In medical books and ordinances anise oil is first mentioned in the *Pharmacopœa Augustana* of 1580, the *Dispensatorium Noricum* of 1589, and the Berlin ordinance of Matthæus Flacco of 1574.

The first accurate investigations of anise oil were undertaken by Th. de Saussure¹²⁾ in 1820, by Dumas¹³⁾ in 1833, by Blanchet and Sell¹⁴⁾ in 1833, by A. Cahours¹⁵⁾ in 1841, by

¹⁾ A. Thær, *Übersetzung und Erläuterung des "Capitulare"*. In Fühling's Landwirtschaftliche Zeitung. Berlin. April number 1878, pp. 241-260.

²⁾ R. Thomson, *Chronicles of London Bridge*. 1827. p. 156.

³⁾ Boorde, *Dyetary of helth*. 1542. — Reprinted for the Early English Text Society. London 1870. p. 284.

⁴⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. Anno 1500. fol. 45.

⁵⁾ See p. 49.

⁶⁾ Gualtherus Ryff, *New gross Destillirbuch*. Frankfurt-on-the-Main 1567. fol. 186.

⁷⁾ Euonymi Philatri *Ein köstl. theurer Schatz*. Zürich 1555 pp. 227 and 301.

⁸⁾ Hieronymi Rubei *Liber de destillatione, in quo stillatitiorum liquorum, qui ad medicinam faciuntur, methodus ac vires explicantur*. Basilæ 1581. Cap. 5, pp. 113 and 143.

⁹⁾ Giov. Bapt. Porta: *Magiæ naturalis libri viginti*. Romæ 1563. p. 379.

¹⁰⁾ Valerii Cordi *De artificiosis extractionibus liber*. Editio Gesner. Argentorati 1561. fol. 226.

¹¹⁾ R. Boyle, *Historia fluiditatis*. London 1661. p. 15.

¹²⁾ Annal. de Chim. et Phys. II. 13 (1820), 280; Schweigger's Journ. f. Chem. u. Phys. 29 (1820), 165.

¹³⁾ Liebig's Annalen 6 (1833), 245.

¹⁴⁾ *Ibidem* 6 (1833), 287.

¹⁵⁾ *Ibidem* 41 (1842), 56; and 56 (1845), 177.

A. Laurent¹⁾ and Gerhardt²⁾ in 1842. Gerhardt called the stearoptene of anise oil anethol and Cahours again pointed out the identity of the stearoptenes of anise and fennel oils, previously recognized by Blanchet.³⁾

OIL OF FENNEL.

Fennel was known to the ancient Chinese, Indians and Egyptians who used it principally as kitchen spice. No mention is made of it in the translations of the Bible. It is frequently mentioned, however, as a garden and medical plant in Roman literature at the beginning of the Christian era,¹⁾ also in the treatises on medicine and distillation of the later middle ages.²⁾ During the latter period fennel appears to have been cultivated and used more extensively than anise.

The oil of fennel has no doubt been known since the time of the preparation of the distilled waters. In the 16. century it appears to have been introduced along with fennel water as a remedy. Its preparation is described by Brunschwig³⁾ and by

¹⁾ Liebig's Annalen 44 (1842), 313.

²⁾ *Ibidem* 44 (1842), 318; and 48 (1843), 234. — Journ. f. prakt. Chem. 36 (1845), 267.

³⁾ Liebig's Annalen 41 (1842), 74.

⁴⁾ Theophrasti, *Veris Opera quae supersunt omnia. De causis plantarum*. Edit. Wimmer. Vol. VI, 10, 3, pp. 16, 18, 99, 101, 310. — Dioscoridis, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, pp. 406, 417. Columella, *De re rustica* in Nisard's *Les agronomes latins*. Paris 1877. Lib. V, cap. 10, p. 303. Plinius *Naturalis historiae libri XXXVII. Lib. XX*, 95, 96. Editio Littré. Vol. 1, p. 334 and vol. 11, p. 39. Palladii *De re rustica*, Editio Nisard, *Les agronomes latins*. 1877. Lib. III, 14, p. 568 and lib. XII, p. 486.

⁵⁾ *Capitulare de villis et cortis imperialibus* 812. Translated and explained by A. Thier in Lühling's Landwirtschaftliche Zeitung. April number 1878, pp. 241-260. Walafridi Strabonis *Hortulus*. In Choulant's *Macer Floridus, De viribus herbarum*. 1832. p. 148. — Ibn-al-Awam, *Livre d'agriculture*, translated by Clément Mullet. 1864. — Ibn-Baitar, *Sammlung der Rohstoffe*. Editio Leclerc, *Traité des Simples*. Paris 1881. Vol. II, p. 164. — Hildegardis Abbatissae *Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne. 1855. Vol. 1154 and 1156. Pfeiffer, *Zwei deutsche Arzneibücher aus dem 12. und 13. Jahrhundert. Sitzungsber. der Kais. Akademie der Wissensch. in Wien*. 42 (1863), 142. (Harsers *Geschichte der Medicin*. 1875. Vol. 1, p. 663.)

⁶⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 47.

Porta.¹⁾ In the municipal ordinances of drugs and spices it is first mentioned in that of Berlin of 1574 and of Frankfurt-on-the-Main of 1582; also in the *Pharmacopœa Augustana* of 1580 and the *Dispensatorium Noricum* of 1589.

Early investigations of fennel oil were made in 1779 by Heyer²⁾ of Braunschweig, in 1792 by Gertinger³⁾ of Eperies in Hungary, and in 1793 by Götting of Jena and by Giese of Dorpat. Further observations, which like the above deal mainly with anethol, were made by Buchner⁴⁾ and by Gœbel. Blanchet and Sell⁵⁾ recognized in 1833 the identity of the stearoptenes from fennel and anise oils. This observation was corroborated in 1842 by Cahours.⁶⁾ Wallach investigated fenchone, a body characteristic of fennel oil, and which possesses considerable theoretical interest on account of its similarity to camphor.

OIL OF LOVAGE.

As a kitchen spice, and possibly also for medicinal purposes, lovage was cultivated and used by the Romans.⁷⁾ Its cultivation north of the Alps was no doubt caused by Charlemagne's *Capitulare* of 812. About the same time, the utility of the plant was praised by Walafrid Strabo and Macer Floridus.⁸⁾ The German medical treatises of the middle ages, beginning with that of the abbess Hildegard of the 12. century, make mention of lovage under various, partly corrupted names. In the treatises on distillation, the distillates of lovage are likewise mentioned.⁹⁾

¹⁾ Giov. Baptistæ Portæ *De destillatione libri IX.* Romæ 1563. p. 379.

²⁾ Crell's Chem. Journ. 3 (1780), 102.

³⁾ Götting's Almanach für Scheidekünstler und Apotheker 14 (1793), 149.

⁴⁾ Buchner's Repert. f. die Pharm. 15 (1823), 163.

⁵⁾ Liebig's Annalen 6 (1833), 287.

⁶⁾ Liebig's Annalen 41 (1842), 74; and Journ. für prakt. Chem. 24 (1841), 359.

⁷⁾ Dioscoridis, *De materia medica libri quinque.* Editio Kühn-Sprengel. 1829. Vol. I, p. 400. Columellæ *De re rustica libri XII.* Lib. XII. 51.

Meyer, *Geschichte der Botanik.* 1855. Vol. 2, p. 74.

⁸⁾ Walafridi Strabonis *Hortulus.* In Choulant's Macer Floridus, *De viribus herbarum una cum Walafridi Strabonis, Othonis Cremonensis et Joannis Folcz carminibus similis argumenti.* Lipsiæ 1832. pp. 141-156. -- Meyer, *Geschichte der Botanik.* 1855. Vol. 3, p. 425.

⁹⁾ Hieron. Brunschwig, *Liber de arte destillandi. De simplicibus.* 1500. fol. 70.

The oil distilled from the root appears to have come into use about the middle of the 16. century. It is mentioned as *Oleum levistici* in the price ordinance of Frankfurt-on-the-Main of 1587, and as *Oleum ligustici* in the 1589 edition of the *Dispensatorium Noricum*.

OIL OF ANGELICA.

Angelica appears to have first come into use as a spice plant during the 15. century,¹⁾ and was no doubt first used for the preparation of the distilled angelica water, the preparation of which is described in Brunschwig's²⁾ and in later treatises on distillation.

The distilled oil of the roots was not prepared until the second half of the 16. century and is first mentioned in the price ordinance of Frankfurt in 1582 and in the *Dispensatorium Noricum* of 1589.

Oil of angelica root was investigated by L. A. Buchner³⁾ in 1842, by F. Beilstein and E. Wiegand in 1882,⁴⁾ by L. Naudin in 1883,⁵⁾ and by G. Ciamician and P. Silber in 1896.⁶⁾

OIL OF ASA FETIDA.

Asant or *asa fetida* was used during antiquity as a spice and as a medicament. As such it is mentioned in Sanskrit and other writings, e. g. in the *Susruta* (Comp. p. 16). The Egyptians and Hebrews do not appear to have used it. According to Gareia (*De aromatibus*), the *silphion* of the Greeks, and the *laserpitium* of the Romans, are identical with *asa fetida*.⁷⁾ Among the later references it is first found in the writings of the Persian

¹⁾ Valerii Cordi *Historia de plantis*. Lib. XI, cap. 135, fol. 158. Flückiger, *Dokumente zur Geschichte der Pharmazie*. 1876. pp. 23, 46, 54, 63, 72, 83, 85. Petri Andrea Matthioli *Commentarii in sex libros Ped. Dioscoridis, De materia medica*. Veneti 1554. fol. 1169.

²⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 20.

³⁾ Buchner's Repert. f. d. Pharm. 76 (1842), 167.

⁴⁾ Berl. Berichte 15 (1882), 1741.

⁵⁾ Bull. Soc. chim. II. 39 (1883), 114.

⁶⁾ Berl. Berichte 29 (1896), 1181.

⁷⁾ Sigismund, *Die Aromata*. Leipzig 1884. p. 45.

geographer Istachri¹⁾ of the 10. century, and those of the Sicilian geographer Edrisi²⁾ of the 12. century. It is also mentioned as medicament in the writings of Ibn Baitar³⁾ of the 11. century, and of Platearius⁴⁾ of the 12. century. In a tariff list of Pisa of 1305 *asa foetida* is mentioned as an article that is imported from Aden via the Red Sea and Mediterranean route.⁵⁾ Its geographic source and botanical origin were first ascertained in 1684—1685 by Adalbert Kämpfer⁶⁾ of Lemgo.

In the mediæval treatises on distillation, *asa foetida* is not used by itself, but as an ingredient in the distillation of spirituous balsams.⁷⁾ The volatile oil of *asa foetida* is apparently first mentioned in the price ordinance of Strassburg of 1685.

OIL OF GALBANUM.

Oriental people, among them the Israelitis, first used galbanum in incense offerings and for fumigations.⁸⁾ It was known to Theophrastus⁹⁾ and Virgil.¹⁰⁾ Dioscorides¹¹⁾ and Pliny¹²⁾

¹⁾ Istachri, *Buch der Länder*. Translated by Mordtmann. Hamburg 1745. p. 111.

²⁾ *Géographie d'Edrisi*, translated by A. Jaubert. Vol. I (1836), p. 450. Meyer, *Geschichte der Botanik*, 1856. Vol. 3, p. 298.

³⁾ Ibn Baitar, *Traité des Simples*. In *Notices et extraits des Manuscrits de la Bibliothèque nationale*. Paris. Vol. I, p. 447. Leclerc, *Histoire de la médecine arabe*. Paris 1874. Vol. I, p. 553.

⁴⁾ Matth. Platearius, *Liber de simpli medicina*. (Circa instans.) In L. Choulant, *Handbuch der Bücherkunde für die ältere Medizin*. Leipzig 1841. p. 299.

⁵⁾ Bonaini, *Statuti inediti della città di Pisa*. 1857. Vol. 3, p. 106.

⁶⁾ Kämpfer, *Amoenitatum exoticarum fasciculi etc.* Lemgoviz 1712. p. 535—552.

⁷⁾ Conrad Gesner, *Anderer Theil des Schatzes Enonymi von allerhand künstlichen und bewerten Ölen etc.* Published by Caspar Wolff. Zürich 1583. fol. 163.

⁸⁾ Exodus, 30:34. — Ecclesiasticus, 24:21.

⁹⁾ Theophrasti *Historia plantarum*. Lib. IX. Cap. 1 and 2.

¹⁰⁾ Virgilii *Georgica*. Lib. III. p. 415.

*Disce et odoratam stabulis accendere cedrum,
Galbanoque agitare gravi nidore chefydros.*

¹¹⁾ Dioscoridis *De Materia medica libri*. Lib. III, 87. Editio Kühn-Sprengel. 1829. Vol. I, p. 437.

¹²⁾ Plinii *Naturalis historiz libri*. Lib. XII. Cap. 25 and 56; and Lib. XXIV. Cap. 5 and 13.

mention Syria as its source. In 176 A. D. galbanum was one of the dutiable Indian spices passing through Alexandria.¹⁾

During the middle ages galbanum is enumerated but sparingly in literature. It is one of the spices enumerated as being in possession of King James of France while a prisoner in England.²⁾ In 1503 it is mentioned as one of the articles of commerce between Venice and London,³⁾ and again in 1581 in one of the French tariff lists.⁴⁾ However, in medical literature of the early middle ages, also in Arabian literature, galbanum is frequently mentioned both as spice and as medicament.

Distilled oil of galbanum was prepared by Walter Ryff,⁵⁾ by Conrad Gesner,⁶⁾ and by Hieronymus Ruheus.⁷⁾ It was included in the 1589 edition of the *Dispensatorium Noricum* and in the *Pharmacopœa Augustana* of 1580, and was mentioned in apothecary and spice ordinances about 1560. Early cursory investigations of the oil were made by Caspar Neumann⁸⁾ about 1728, by Walter⁹⁾ in Leipzig about 1744, by Fiddichow¹⁰⁾ in 1815, and by W. Meissner¹¹⁾ in 1816.

OIL OF GUM AMMONIAC.

The air-hardened gumresin of *Dorema ammoniacum*, Don. (*Peucedanum ammoniacum*, H. Baillon) and of several species of *Ferula*, produced by the puncture of insects, was used during antiquity for incense, for embalming and, in all probability, for

¹⁾ Vincent, *Commerce and Navigation of the Ancients in the Indian Ocean*. London 1807. p. 692. — Meyer, *Geschichte der Botanik*. 1855. Vol. 2, p. 167.

²⁾ Douët d'Arcq, *Comptes de l'Argenterie des rois de France*. 1851. p. 236.

³⁾ Pasi, *Tariffa de Pes e Misura*. Venetia 1503. fol. 204.

⁴⁾ Fontanon, *Edicts et Ordonnances des rois de France*. 1585. Vol. 2, p. 388.

⁵⁾ Gualtherus Ryff, *New gross Destillirbuch*. 1545. fol. 179. See also p. 48.

⁶⁾ See p. 53. Ewonymus Philiatrus, *Ein köstlicher theurer Schatz*. 1555 p. 237.

⁷⁾ Hieronymi Rubei, *Liber de destillatione*. Basilæ 1581. Cap. 5, p. 148.

⁸⁾ Caspar Neumann, *Chymia medica dogmatico-experimentalis*. Editio Kessel. 1749, p. 422. Zimmermann, *Prælectiones chemicæ*. Berlin 1740, p. 853.

⁹⁾ A. F. Walther, *De oleis vegetabilium essentialibus*. Dissertatio. Lipsiæ 1745.

¹⁰⁾ Berl. Jahrbuch der Pharm. 1816, 230.

¹¹⁾ Trommsdorff's Neues Journ. der Pharm. 1, I. (1817), 3.

medicinal purposes as well. In ancient literature both the plant and the gumresin are mentioned repeatedly. Both Dioscorides¹⁾ and Pliny²⁾ mention that the gumresin was named after that of the temple of Jupiter Ammon in the Libyan desert in the neighborhood of which it was produced. Dioscorides' description seems to harmonize with that of *Ferula marmarica*, Aschers et Taub., found in Barka (Cyrenaica). Later the African gumresin was replaced by that from *Dorema ammoniacum*, Don. Hence the translators of Dioscorides into Arabian, some of whom were Persians, erroneously applied the Persian name *Uschag* also to the African gumresin.³⁾ One of the earliest mentions of ammoniac is to be found in an Alexandrian tariff list for Indian goods, which was compiled during the years 176 to 180 A. D. under the emperors Marcus Aurelius and Commodus.⁴⁾ Persian ammoniac is mentioned as medicament under the Persian name *Uschag* during the 10. and 11. centuries in the writings of the physicians Isaac Judæus⁵⁾ and Alhcrvi in Bochara.⁶⁾ Other ancient medical treatises, among them those of Scribonius Largus, Alexander Trallianus, and others, mention the gumresin as a current drug.

The oil of gum ammoniac was distilled by Walter Ryff,⁷⁾ Val. Cordus, and Conrad Gesner.⁸⁾ It is included in the Frankfurt tax for the year 1587, and in the *Dispensatorium Noricum* of 1589.

The earlier investigations were made by Buchholz⁹⁾ of Erfurt in 1808, by Calmeyer¹⁰⁾ of Hamburg in 1808, by H. Braconnot¹¹⁾ in 1809, and by Hagen¹²⁾ of Königsberg in 1814.

¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. I, p. 439.

²⁾ Plinii *Naturalis historiae libri*. Liber XII, cap. 25.

³⁾ O. Stapf, Kew Bull. 1907 (No. 10), 375. Report of Schimmel & Co., April 1908, 14.

⁴⁾ Meyer, *Geschichte der Botanik*. 1855. Vol. 2, p. 167.

⁵⁾ Isaaci Judæi *Opera omnia*. Lugduni 1515. Lib. II. Cap. 44. In Choulant's *Handbuch der Bücherkunde für die ältere Medicin*. Leipzig 1841.

⁶⁾ F. R. Seligmann, *Codex Vindobonensis. Liber fundamentorum Pharmacologiae*. 1830. p. 35.

⁷⁾ Gualtherus Ryff, *New gross Destillirbuch*. 1567. fol. 177b. See also p. 46.

⁸⁾ See p. 53. Euonymi Philatri *Ein köstlicher theurer Schatz*. 1555. p. 237.

⁹⁾ Buchholz, *Taschenbuch für Scheidekünstler und Apotheker* 1809, 170.

¹⁰⁾ Trommsdorff's Journ. der Pharm. 17, II. (1808), 82.

¹¹⁾ Ann. de Chim. 68 (1808). — Trommsdorff's Journ. d. Pharm. 18, I. (1809), 202.

¹²⁾ Berl. Jahrbuch der Pharm. 1815, 95.

OIL OF DILL.

Dill was known during antiquity.¹⁾ With other kitchen spices the dill plant is mentioned in Sanskrit literature, and in the Bible.²⁾ Like that of fennel, anise, and caraway, its cultivation was early extended over the countries of Europe. It was cultivated in England as early as the 10. century.³⁾

In the treatises on distillation of the 15. and 16. centuries the distillation of dill is mentioned frequently.⁴⁾ In German drug and spice ordinances dill oil is first mentioned in that of Frankfurt-on-the-Main of 1587.

OIL OF WINTERGREEN.

The distillation of oil of wintergreen⁵⁾ was probably begun in the first decades of last century along with that of sassafras bark (p. 129) and birch bark (p. 118) in the states of Pennsylvania, New Jersey and New York. At first these aromatics were used for chewing, later for the preparation of refreshing beverages and home remedies, and especially for the much used, so-called blood purifiers. After the production of these volatile oils had been made a success they were often used instead of the aqueous extracts of the drugs. This use is of considerable importance to the history of the introduction of wintergreen and

¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. I, p. 405.

²⁾ Matth., 23:23. In English translations of the Bible, since the days of Wyckliff [1380], the Greek *ανιθον* has been translated as anise. Luther translates it more correctly as dill, which is always meant in Greece when *ανιθον* is used. (Langkavel, *Botanik der späteren Griechen*. Berlin 1866. p. 39.)

³⁾ *Herbarium Apulei*. In Leechdoms, Wortcunning and Starcraft of early England, edited by Cockayne. London 1864. Vol. I, pp. 219, 235, 237, 281, 293. - Popular Names of British plants. London 1870.

⁴⁾ Hieronymus Brunschwig, *Liber de arte destillandi*. 1500. Fol. 40.

⁵⁾ Upon the suggestion of Kalm, after his return to Sweden, Linné named the plant *Gaultheria procumbens* in honor of Dr. Gaultier, a French physician and botanist in Quebec, whom Kalm had met in 1749. Kalm, who had obtained herbarium specimens of the plant from John Bartram of Philadelphia, with the latter regarded it as a species of *Trientalis*. (Peter Kalm's *Reise nach dem nördlichen Nordamerika im Jahre 1748-1749*. Göttingen 1754. Vol. 3, pp. 283, 421, 477, 515 and 533.)

sassafras oils, in as much as both of these were used as popular remedies (socalled patent medicines) in the United States since the beginning of last century. The preparation and use of these remedies soon became general, and with it came a greater demand for these oils. Wintergreen oil was especially in demand for the preparation of one of the oldest popular remedies in the United States, namely Swaim's *Panacea*,¹⁾ introduced in 1815, which at that time had an enormous sale and in the efficiency of which great confidence was placed.

Wintergreen oil does not appear to have been used for other purposes at that time. The first mention of it in literature is found in a botanical work published in 1818 by Bigelow,²⁾ a physician of Boston. In it, gaultheria oil is mentioned as a staple article of the drug stores. He further states that this oil occurs also in *Spiræa ulmaria*, the root of *Spiræa lobata*, and especially in the bark of *Betula lenta*. In pharmacopœias, the oil was first taken up in that of the United States of 1820. The medicinal use of the oil, however, did not become general until 1827, when the New York Medical Society made known its use in the preparation of the popular specific mentioned above.³⁾

Although the similarity of the volatile oil from *Gaultheria procumbens*, L., to that from the bark of *Betula lenta*, L., was known before 1818,⁴⁾ the identity of their principal constituent was shown scientifically in 1842 by Wm. Procter jr.⁴⁾ of Philadelphia and in 1844 by A. A. Th. Cahours⁵⁾ of Paris. From that time on the oil was no longer distilled exclusively from wintergreen, but often from this together with birch bark, or only from the latter. The oil came more and more into use as an aromatic for pharmaceutical and cosmetic preparations, for beverages and

¹⁾ This remedy was an imitation of the *Rob de Lalleteur*, a secret remedy exploited with great success by the Parisian apothecary Boiveau at the beginning of the last century. Swaim, a bookdealer in Philadelphia, had been cured by this remedy. He succeeded in securing the formula, and after substituting gaultheria oil for sassafras oil, he introduced it into commerce. (Pharm. Review 16 [1898], 179.)

²⁾ Jacob Bigelow, American Medical Botany. Boston 1818. Vol. 2, p. 28.

³⁾ Pharm. Review 16 (1898), 179. — Americ. Journ. Pharm. 3 (1831), 199.

⁴⁾ Americ. Journ. Pharm. 14 (1842), 211. — Liebig's Annalen 48 (1843), 66.

⁵⁾ Annal. de Chim. et Phys. III. 10 (1844), 327—358 and Liebig's Annalen 48 (1843), 60; 52 (1844), 327.

medicinal remedies,¹⁾ and thus became an important article of commerce.

As artificial oil of wintergreen, methyl salicylate has been produced on a commercial scale by Schimmel & Co. since 1886. It was made official in the 1890 edition of the U. S. Pharmacopœia.

OIL OF ROSEMARY.

Rosemary was greatly esteemed by the Greeks and Romans,²⁾ and also by the Arabians.³⁾ Like the laurel, rosemary was employed by the former as a decorative plant in religious rites and in hero cult. In as much as the plant was not used for medicinal or other practical purposes, rosemary was given but little attention in mediæval literature. However, it received prominent mention in the *Capitulare* of Charlemagne of 812; among the seventy-three economic plants recommended therein also in the drug inventory of Platearius⁴⁾ of the 12. century.

The first mention of the distillation of rosemary is found in the writings of Arnoldus Villanovus⁵⁾ of the 13. century. He distilled, probably for medicinal purposes, turpentine oil and rosemary oil. An alcoholic distillate of both oils or of rosemary only was in use for centuries as the first popular perfume under the name of Hungarian water.⁶⁾ The distillation of the oil is described more fully by Raimund Lullus,⁷⁾ a disciple of Villanovus.

¹⁾ New York Medical Record 22 (1882), 505. — Squibb's *Ephemeris* (New York) 3 (1892), 930.

²⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829, p. 424.

³⁾ Ibn el Baltar, *Liber magnæ collectionis simplicium alimentorum et medicamentorum*. Translated by Jos. Sontheimer. Stuttgart 1840. Vol. I, p. 73.

⁴⁾ Matthæi Platearii *Liber de simplicium medicina*. In Choulant's *Handbuch der Bücherkunde für die ältere Medizin* etc. Leipzig 1841. p. 229.

⁵⁾ Arnoldi Villanovi *Opera omnia*. Cap. *De vinis*. Veneti 1595. p. 589 to 590.

⁶⁾ Pp. 30 and 66. — Sapata, *Mirabilia seu secreta medico-chirurgi per D. Spießium*. Ulm 1696. p. 49.

⁷⁾ *Postquam singulorum individuum dictorum lentissimo igne aquæ destillatæ fuerit, amoto priori recipiente aquam destillatam optime occlusam servabis et annexo altero recipiente augebis ignem ut deinde destillet oleum cuiusque, quod proicias, quia nihil valet, excepto eo quod e rore marino extraxeris, quod servabis, cum in se aliquid virtutis contineat.* — Raimundi Lulli *Experimenta novissima*. In Magnet's *Bibliotheca chemica curiosa*. Genevæ 1702. Vol. I, fol. 829.

Oil of rosemary was a much used oil in the middle ages, and is often mentioned in the writings of that period. It is described in the index of the Compendium of Saladin¹⁾ at the end of the 15. century and in the works of Brunshwig,²⁾ Ryff,³⁾ Gesner,⁴⁾ Porta,⁵⁾ and others, and is mentioned in drug and spice ordinances of the 15. century. In several of the treatises on distillation, and in medical works of the 14. and 15. centuries, an empyreumatic oil of rosemary is also mentioned.⁶⁾

One of the first investigations of rosemary oil was made in 1720 by the Parisian apothecary Cl. J. Geoffroy.⁷⁾ A century later it was more fully investigated by Th. de Saussure,⁸⁾ and in 1837 by Kane.⁹⁾ In 1734 Cartheuser¹⁰⁾ determined the yield of oil.

The so-called rosemary camphor was first noticed in 1685 by Joh. Kunkel¹¹⁾ of Berlin, and a century later (1785) by Arezula¹²⁾ of Cadiz. Proust¹³⁾ prepared it in 1800.

OILS OF LAVENDER AND SPIKE.

Originally the oily distillates from the several species of lavender were all designated spike oil. It was not until the close

¹⁾ Saladini Asculani *Compendium aromatariorum*. Venet. 1488. Index.

²⁾ See p. 39 and 47.

³⁾ Gualtherus Ryff, *New gross Destillirbuch*. 1545. p. 186.

⁴⁾ Page 52. - Euonymi Philatri *Ein köstlicher theurer Schatz*. 1555. pp. 226, 249, 273.

⁵⁾ Joh. Bapt. Porta *Magiæ naturalis lib. viginti. Liber de destillatione*. p. 385.

⁶⁾ Christ. Lindner, *De oleis destillatis empyreumaticis*. Dissertatio, Francofurti ad Viadrum. 1744.

⁷⁾ *Mémoires de l'Académie des sciences de Paris*. 1721. p. 163.

⁸⁾ *Annales de Chim. et de Phys.* II. 13 (1820), 278.

⁹⁾ *Transact. of the Royal Irish Acad.* 18, 135. — *Journ. f. prakt. Chem.* 15 (1838), 156.

¹⁰⁾ Fr. Cartheuser, *Elementa Chymiae dogmatico-experimentalis, una cum synopsi Materiae medicae selectioris*. Halæ 1736. II. p. 83 and 106.

¹¹⁾ Joh. Kunkel, *Probierestein. Fünf curinse chymische Tractatelein nebst einer Vorrede*. Frankfurt-on-the-Oder and Leipzig 1721. p. 397. "Mein gnädigster Kurfürst hat mir einsten des alten verstorbenen Thurnhüusers Apotheke geschenkt, darinne noch viele Olea destillata seynd, die noch so frisch, als wenn sie diese Stund destilliret wären. Darunter ist ein Gläslein mit oleo Anthos, darinne ein Sal angeschossen ist."

¹²⁾ Page 74. — Arezula, *Resultado de las experiencias hechas sobre el alcantor de Murcia con licencia*. Segovia 1789. p. 8.

¹³⁾ Trommsdorff's *Journ. der Pharm.* 8, II. (1800), 221.

of the 16. century that a distinction was made between spike oil and lavender oil.¹⁾

In all probability, *Lavandula Stæchas*, L., which is indigenous to the Mediterranean coast lands, and which is characterized by its aromatic violet-red inflorescence, was first used in the distillation of spike oil.

The spike or stæchas oil²⁾ mentioned in the writings of Dioscoridis,³⁾ Pliny,⁴⁾ Scribonius Largus,⁵⁾ and their contemporaries was, in all probability, only an aromatized fatty oil, like rose, spikenard and other aromatic oils used during antiquity.⁶⁾

It is not at all improbable that the Phoccans, Greek colonists from Asia Minor, who about 600 B. C. colonized the coast of the Bay of Lyons and founded Marseille, brought with them *Lavandula Stæchas* as well as other native plants and introduced them into southern France, whence they soon spread over Spain. Apparently the *L. Stæchas* was used together with the spike (*L. Spica*) during the middle ages, whereas *Lavandula vera* and *Lavandula latifolia*⁷⁾ were used later. Indeed, the name *Lavandula* had its origin in Italy during the later middle ages.

Spike, occasionally designated nard, was used during the early middle ages by the physicians of the Alexandrian School. In European medical treatises we find it recommended by the

¹⁾ F. de Gingins-Lassaraz, *Histoire des Lavandes*. Geneva and Paris 1826.

²⁾ Because of the supposed similarity in odor, *Lavandula Stæchas*, which was used during antiquity, was confounded with *Nardostachys jatamansi*, D. C., the rhizome of which was likewise prized as a spice and as an incense. The latter was named *Nardus indica*, the former *Spica Nardi*. During the middle ages, the former was also designated *Nardus italica* and *Nardus celtica*. In the pharmacopœias the flowers of this plant were known as *Flores stæchados arabicæ*. (Camerarius, *Hortus medicus et philosophicus*. Francofurti 1588, p. 164.) See also *Nardostachys*.

³⁾ Dioscoridis, *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, pp. 15, 17, 35, 40, 62, 508, 542.

⁴⁾ Plinii *Naturalis historiae libri XXXVII*.

⁵⁾ Scribonii Largi *Compositiones medicamentorum*. Editio Helmreich. Leipzig 1887. p. 72. — Meyer, *Geschichte der Botanik*. 1855. Vol. 1, p. 33.

⁶⁾ See p. 37, 137 and 145.

⁷⁾ M. Platearius, *Liber de simplicibus medicinis*. (Circa instans.) In Choulant, *Handbuch der Bucherkunde für die ältere Medizin*. 2. ed. Leipzig 1841. p. 299.

Abbeſs Hildegard¹⁾ for the preparation of an eye remedy. As early as the 14. century, ſpike as well as narde flowers were uſed for filling pillows for healthy perſons as well as the ſick.²⁾ Brunſchwig refers to ſpike as to a univerſally known plant.³⁾

The diſtilled ſpike or ſpikenard oil was probably known in the 15. century. As *Oleum de Spica* from the Provence,⁴⁾ it is the only diſtilled oil, beſides cedar (turpentine) oil, mentioned by Hieronymus Brunſchwig in his *Destillirbuch* of 1500. Saladin alſo mentioned ſpikenard oil at the end of the 15. century.⁵⁾

In his *Dispensatorium Noricum* of 1543 Valerius Cordus mentioned only three diſtilled oils: turpentine oil, juniper oil and ſpike oil.⁶⁾ Ryff deſcribed in his treatiſe on diſtillation, published ſomewhat earlier, the diſtillation of "*Spik und anderen lürnemen Olen*", and added the ſtatement that, "*das Spiken- oder Lavendelöl gemeyniglich aus der Provinz Frankreich gebracht wird in kleinen gläſſlin eingeläſst und theuer verkaufft*".⁷⁾ In the 16. century the ſeveral ſpecies of lavender were cultivated in Germany⁸⁾ and in England.⁹⁾

Conrad Geſner uſed the name ſpike oil only and deſcribed the diſtillation of the ſpike bloſſoms,¹⁰⁾ whereas Giovanni

¹⁾ Hildegardis Abbatissæ *Subtilitatum diversarum naturarum, creaturarum libri novem*. Editio Migne. 1855. pp. 1140 and 1143.

²⁾ Duët d'Arcq, *Comptes de l'Argenterie des rois de France*. 1874. Vol. 2, p. 148.

³⁾ Hieronymus Brunſchwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 72.

⁴⁾ *Ibidem* fol. 72. - See p. 39.

⁵⁾ Saladini *Compendium aromatariorum*. Venet. 1488. Index.

⁶⁾ *Dispensatorium Noricum*. Autore Valerio Cordo. Editio Paris 1548. p. 439. *Ex majori lavendula quæ spica vocatur, apud nos majoribus sumptibus lit quam in Gallia Narbonensi, ideo potius emendum est a mercatoribus qui illud e Gallia allerunt.*

⁷⁾ Gualtherus Ryff, *New gross Destillirbuch*. fol. 186. Compare alſo p. 46.

⁸⁾ Conrad Geſner, *De hortis Germaniæ liber recens*. Argentorati 1561. fol. 264.

⁹⁾ Meddygon Myddfal. Edit. John Pughe. Llandovery 1861. p. 287.

¹⁰⁾ „Die Blümlein der Spiken oder des Lavanders ſolt du eine kurze zeyt lang ſonnen in einer groſſen gläſinen retorte und darnach ein wasser in einem Alembik darvonn deſtilliren und abziehen. Dieſes wasser durch den ganzen Sommer geſetzt an eine warme ſtatt an die Sonnen ſo treybt lür und lür öl über ſich, welches öl du althwägen ſolt von dem wasser

Baptista Porta,¹⁾ at the end of the 16. century, described also the distillation of lavender blossoms and especially emphasized the superiority of the oil from the French lavender.

An interesting description of the preparation of the French spike or lavender oil is contained in a treatise published in 1773 by Joh. Frances Demachy,²⁾ who was director of the laboratories of the Paris municipal hospitals. In its essential features this description corresponds with that quoted on p. 48.

separieren und abslündern mit einem läderlin und dasselbe fleissyg hehal in emer gläsinen gntteren (Flasche) wohl vermachet und verstopfet." Thesaurus Euonymi Philatri seu köstlicher theurer Schatz. Zürich 1555. p. 222.

¹⁾ G. B. della Porta, *Magiae naturalis libri viginti. Liber de destillatione*. Romae 1567. fol. 87. "... e spica fragrantior excipitur, est illud quod ex Gallia provenit." — *Ibidem* p. 54 and 78: "tanta odoris fragrantia ut omnes flores odoris jucunditate provocet."

²⁾ „Dieses Öl, welches fast ebenso gemein ist, als das Terpentινό, mit dem es fast alle Schriftsteller verwechseln, oder in Verdacht gestanden haben, es werde damit verläscht, wird auf freiem Felde von Schäfern und anderen Hirten in Languedoc und Provence verfertigt."

„Wenn die Gattung Lavendel, welcher Lavendel oder Aspic genannt, welcher auf Hügeln und Wiesen dieser Provinzen häufig wächst, in Blüte ist, gehen die Schäfer zur Stadt um bei den Kaulanten, die mit dem Öle handeln, eine grosse kupferne Blase und verzinnem Hute, und einem etwas hohen Dreifuß zu holen. Sie lagern sich in einer Wiese neben einem Bache und destilliren das Spököl folgender Gestalt. Sie schneiden die blühenden Spitzen der Spike ab, füllen die Blase damit, gießen Wasser hinzu, setzen den Hut dicht auf, zünden mit trockenen Kräutern ein gutes Feuer unter dem Dreifuß, und legen in einer grossen gläsernen Flasche dasjenige auf, was strahlungs herüber läuft. Wenn sie herüber gezogen haben, was die Erfahrung ihnen gelehrt hat, wieviel die Ladung einer Blase giebt, so leeren sie sie aus, füllen mit frischen Blumen und legen wieder an zu destilliren. Sie tun dies von Ort zu Ort bis die Blütezeit vorüber ist. Sie füllen das abgesonderte Öl in lederne Schläuche. Wenn der Sommer vorüber ist, kommen die Destillateure zu Stadt, überliefern ihren Apparat dem Eigentümer und verkaufen ihm zu sehr mässigem Preise die Frucht ihrer Nebenstunden, welcher reiner Profit für sie ist. Sie lassen zuweilen absichtlich Wasser im Öle, was man ihnen für Öl bezahlen würde, wenn man nicht die Vorsicht brauchte, die Schläuche einige Tage aufgerichtet liegen zu lassen, ehe man das Öl ausfüllt; öffnet man nun, so kommt das Wasser zuerst heraus."

„Dieses Öl ist im Geruche nicht eins der feinsten, dennoch aber vom Terpentινόle durch eine gelbliche Farbe und seinen Lavendelgeruch verschieden. Die Firnilmaler brauchen viel davon."

J. F. Demachy, *L'art du distillateur des eaux fortes*. Paris 1773. German edition *Laborant im Grossen* by Sam. Hahnemann. Leipzig 1784. Vol. 1, p. 250.

In medical works *Oleum spicæ* was mentioned as early as the 14. century.¹⁾ It was included in the first edition of the *Dispensatorium Noricum* of 1543. *Oleum lavandulæ* is also mentioned, together with spike and other essential oils, in the 1589 edition. The *Pharmacopœa Augustana* of Occo, contains up to 1613 only *Oleum spicæ*; from that date on also *Oleum lavandulæ*.

Spike oil is mentioned in the oldest drug and price ordinances of German cities; *Oleum lavandulæ*, however, is not found until 1582 in the Frankfurt ordinance.²⁾

The statements of Demachy and other writers of his time agree with the assertions of later authors, that the spike oil found in commerce in the 18. century was probably only a distillate or mixture of turpentine and lavender oils.³⁾

The yield of oil from the distillation of spike and lavender blossoms appears to have been first mentioned by W. Lewis,⁴⁾ also by Friedr. Cartheuser.⁵⁾ The so-called "lavender camphor" was observed in 1785 by Arezula,⁶⁾ and in 1800 by Proust. The first investigations of lavender oil were made by Saussure.⁷⁾

OIL OF SAGE.

Sage appears to have been used as a medicinal herb at the time of the Romans⁸⁾ and was one of the plants recommended by Charlemagne for cultivation.⁹⁾ In the "Destillirbuch" by Brunschwig of 1500 a distinction is made between large and small sage.¹⁰⁾

¹⁾ Pfeiffer, *Zwei deutsche Arzneibücher des 12. und 13. Jahrhunderts*. In *Sitzungsberichte der Wiener Akad. der Wissensch.* 1868, Vol. 42, p. 124.

²⁾ *Register aller apothekischen Simplicien und Compusiten, so in den beiden Messen zu Frankfurt a. M. durch die Materialisten, Kaulfleut, Wurzelträger, Kräutler, auch durch die Apotheker daselbst verkauft werden.* 1582.

³⁾ Dulk, *Commentar zur Pharmacopœa Borussica*. 3. ed. 1833. Vol. 1, p. 643.

⁴⁾ Wm. Lewis, *The new Dispensatory*. London 1746.

⁵⁾ F. Cartheuser, *Elementa chymicæ dogmatico-experimentalis*. Halæ 1736. Vol. 2, pp. 133 and 149.

⁶⁾ Arezula, *Resultado de las experiencias hechas sobre alcanfor de Murcia non licencia*. Segovia 1789.

⁷⁾ *Annal. de Chim. et Phys.* 4 (1790), 318; 13 (1792), 273; 40 (1804), 159.

⁸⁾ Theophrasti *Historia plantarum*. Lib. VI, cap. 2. — Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel 1829. Vol. 1, p. 381. Vol. 2, p. 510.

⁹⁾ *Capitulare de villis et cortis imperialibus*. Anno 812. Translated and explained in Fühling's *Landwirtschaftl. Zeitung*. April number 1878. pp. 241 to 260.

¹⁰⁾ Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 103.

for the distillation of sage water. Furthermore a species of *Eupatorium*, the *Kunigundenkraut*, is referred to as wild sage and directed to be distilled.¹⁾

The distilled oil of sage²⁾ is first mentioned in the price ordinances of Worms of 1582, and of Frankfurt of 1587. It is also included in the 1589 edition of the *Dispensatorium Noricum*. In 1688, the distillation of the oil was described by Begnini.³⁾ The yield of oil from the leaves was determined by Wedel⁴⁾ in 1715 also by Friedr. Cartheuser⁵⁾ about 1732. In 1720 Cl. J. Geoffroy observed a stearoptene which had crystallized from the oil, and which he termed sage camphor.⁶⁾ The same substance was again observed by Arezula⁷⁾ of Cadiz in 1789 and described by him.

The first examination of the leaves appears to have been made by Illisch⁸⁾ of Riga in 1810; whereas the oil was investigated by Herberger⁹⁾ in 1829 and by Fr. Rochleder¹⁰⁾ in 1841.

OIL OF BALM.

On account of its fragrance, balm was cultivated by the Greeks, Romans, and Arabs,¹¹⁾ and during the middle ages in Italy, Germany¹²⁾ and Scandinavia.¹³⁾

¹⁾ Brunswig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 117.

²⁾ See p. 33.

³⁾ Johannis Begnini *Tyrocinium chymicum*. In Joh. Hartmanni *Opera omnia medico-chymica congesta atque pluribus aucta a Conrado Johrenio. Francofurti ad Mœnum*. 1690. Vol. III, p. 27.

⁴⁾ Wedel, *Dissertatio de Salvia*. Jenæ 1715.

⁵⁾ Cartheuser, *Elementa chymicæ dogmatico-experimentalis, una cum synopsis Materiae medicæ selectioris*. Halæ 1736. Vol. 2, p. 87.

⁶⁾ *Mémoires de l'Académie royale des sciences de Paris*. 1721. p. 163.

⁷⁾ Arezula, *Resultado de las experiencias hechas sobre el alcanfor de Murcia con licencia*. Segovia 1789, p. 8.

⁸⁾ Trommsdorff's *Journ. der Pharm.* 20, II. (1811), 7.

⁹⁾ Buchner's *Repert. f. d. Pharm.* 34 (1830), 131.

¹⁰⁾ Liebig's *Annalen* 44 (1842), 4.

¹¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829, p. 453. - Platearius, *Circa instans*. Editio Choulant. 1841. Vol. 1, p. 299. - Macer Floridus, *De viribus herbarum etc.* 1832. Editio Choulant, p. 64. - Plinii *Naturalis historiae libri 37*. Lib. XX, 45; Lib. XXI, 86. Editio Littré, 1877. Vol. 2, p. 18 and 66. - Varro, *De agricultura*, Lib. III, 16. Editio Nisard, p. 149. - Meyer, *Geschichte der Botanik*. Vol. 1, p. 362.

¹²⁾ Conradi Gesneri *De Hortis Germaniæ liber recens*. 1561. Fol. 267b.

¹³⁾ Henrik Harpestreng, *Danske Lægehok*. Copenhagen 1826, p. 118.

During the period of distilled waters, from the 15. to the 17. centuries, balm water was a current article. Oil of balm appears to have come into use about the middle of the 16. century. It is first mentioned in the ordinance of Frankfurt-on-the-Main for 1582 and in the *Dispensatorium Noricum* of 1589.

Comparable to the distillate from rosemary of the 16. century, which was the precursor of the *Eau de Cologne* of the 18. and 19. centuries, the fragrant distillate from balm, lemon peel and lavender of the 17. century developed later into a very popular perfume. It was first prepared by the Carmelite monks of Paris in 1611 and became famous as *Eau des Carmes* (Ger. *Karmelitergeist*).¹⁾ Later the alcoholic distillate was made officinal as *Spiritus Melissæ compositus*.

The earlier investigations of the oil were made by Schultz²⁾ in 1739, by Friedr. Hoffmann³⁾ about the same time, and by Delinc⁴⁾ in 1779.

OIL OF HYSSOP.

In antiquity hyssop was already included among the spice plants.⁵⁾ The word "Ysop", used by Luther in his translation of the Bible, did not apply to hyssop but to *Origanum*.⁶⁾ The volatile oil thereof was used during the late middle ages and is mentioned in the German price ordinances of the 16. century.

OIL OF THYME.

As a kitchen spice thyme was used during antiquity.⁷⁾ Theophrastus, Dioscorides, Pliny and Columella⁸⁾ mention thyme and

¹⁾ See p. 67.

²⁾ Schultz, *Dissertatio de Melissa*. Halæ 1739.

³⁾ Friedr. Hoffmannii *Observationum physico-chemicarum selectiorum*. Halæ 1722 1736. Lib. III, p. 19.

⁴⁾ Crell's *Chemische Annalen* 3 (1780), 29.

⁵⁾ Prosper Alpinus, *De plantis Ægypti liber*. Veneti 1591. Cap. 20. — Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel 1829. Vol. 1, p. 374. — 1. Kings, 4: 33. — Exodus, 12: 22. — Lev. 14: 4; Numbers, 19: 6 and 18.

⁶⁾ Rosenmüller, *Handbuch der bibl. Altertumskunde*. 1830. Vol. 4, p. 108.

⁷⁾ Apocalypse, 18: 13.

⁸⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 385. — Plinii *Naturalis historię libri* 37. Lib. XXI, 31. — Columellæ *De re rustica*. Editio Nisard. 1877, p. 446.

distinguish it from wild thyme or *Thymus Serpyllum*, whereas the two were not always kept separate by writers during the middle ages. It is probably for this reason that Valerius Cordus¹⁾ refers to thyme as *Thymus nostras*.

Although it never played an important role in medical practice, it, as well as the oil distilled therefrom, has been officinal in the medical treatises since the 16. century, also in the drug and spice ordinances. The oil was introduced into the 1589 edition of the *Dispensatorium Noricum*.

Thyme camphor (thymol) was first observed by Caspar Neumann²⁾ in 1719, then by Friedr. Cartheuser³⁾ in 1754. It was examined by Lallemant⁴⁾ in 1853 who named it thymol.

MENTHA OILS.

Several mints, the botanical identity of which it may be impossible to establish, were known during antiquity, being used as kitchen spice,⁵⁾ possibly also as medicament by the Egyptians,⁶⁾ Hebrews⁷⁾ and Romans.⁸⁾ A similar use the mints seem to have found with the Germanic tribes. Among the 73 economic plants recommended for cultivation in his *Capitulare* of 812 by

¹⁾ Val. Cordi *Historiæ plantarum*. Editio C. Gesneri. Argentorali, 1561. p. 136.

²⁾ Philosophic. Transactions of the Royal Soc. of London. 1724, 1725, 1733, 1734. — *Chymia medica dogmatico-experimentalis* 2, 282, and *Lectioes chymicæ de salibus alcalinofixis et de camphora*. Berlin 1727. pp. 135—137.

³⁾ Cartheuser, *De sale volatile oleoso solido in oleis æthereis nonnumquam reperto*. Dissertatio. Francofurti 1774. — Cartheuser, *Materia medica*. Vol. 2, p. 115.

⁴⁾ Journ. de Pharm. et Chim. III. 24 (1853), 274; Compt. rend. 37 (1853), 498.

⁵⁾ Prosper Alpinus, *De plantis Ægypti liber*. Veneti 1591. Cap. 42, p. 61.

⁶⁾ G. Schweinfurth, *Ueber Pflanzreste aus altägyptischen Gräbern*, in *Berichte der deutsch. botan. Gesellschaft* 2 (1884), 366.

⁷⁾ Matth., 23: 23. Luk., 11: 42.

⁸⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829 p. 383. — Plinii *Naturalis historiæ libri*. Lib. XIX, cap. 8: "*Grato mentha mensas odore percurrit in rusticis dapibus*." Lib. XX, cap. 14: "*Menthæ ipsius odor animum excitat, et sapor aviditatem in cibis; ideo embannatum musturæ familiaris*." — Columellæ *De re rustica*, Lib. XI, 3. Editio Nisard, "*Les agronomes Latins*." Paris 1877. p. 445.

Charlemagne,¹⁾ three mints are mentioned. Two of these belonged to what is now regarded as the genus *Mentha*, viz., the *Mentha Menthastrum* and *Sisymbrium* (*Mentha crispa*).²⁾ In the writings of the abbess Hildegard³⁾ of 1160, *Bachmyntza*, *Myntza major*, *Rosmyntza*, and *Römische Myntza* are mentioned. In the Pharmacopœia of Gotha⁴⁾ of the beginning of the 15. century *Cruseminte* is also mentioned.

In like manner the treatises on distillation of the 15. and 16. centuries give directions for the preparation of distilled waters from mints without further characterization of the plants.⁵⁾ The mint oils mentioned in the older pharmacopœias and drug ordinances, likewise, reveal an uncertainty concerning the origin of the different kinds. Thus the Berlin ordinance of 1574 mentions only *Oleum menthæ*. The Frankfurt list of 1582 mentions *Oleum menthæ*, *Oleum polemii* and *Oleum pulegii*.

OIL OF PEPPERMINT.

Whether or not peppermint was among the mints used during the middle ages can no longer be determined. In the oldest German treatise on distillation the *Liber de arte distillandi*⁶⁾ of the year 1500, the following mints are mentioned as being used in the preparation of distilled waters: *Mentha aquatica*, *Mentha rubra*, *Mentha balsamica*, *Mentha sarracenicæ* and *Mentha crispa*, but no distinguishing characteristics are given. Neither is it definitely known whether the kinds of mint used formerly agree with those now in use. As far as known, the only spe-

¹⁾ *Capitulare de villis et cortis imperialibus*. Translated and explained by A. Thaer. In Fühling's Landwirtschaftliche Zeitung. April number 1878. p. 241—260.

²⁾ Meyer, *Geschichte der Botanik*. 1856. Vol. 3, p. 406.

³⁾ Hildegardis Abbatisæ *Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne. 1855. p. 1161.

⁴⁾ Karl Regel, *Das mittelhochdeutsche Gothaer Arzneibuch*. Gotha 1873. p. 21.

⁵⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 75b. Val. Cordus, *Dispensatorium Noricum*. Editio Parisiæ. 1548. pp. 77, 284, 285, 378, 381, 418, 419, 432. — Gesner, *De Hortis Germaniæ liber recens*. 1561.

⁶⁾ Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 75.

cimens of *Mentha piperita* which are several hundred years old, are found in the herbarium of the British Museum in London. John Ray,¹⁾ the English naturalist, had obtained them from the county of Hertfordshire of southern England in 1696 and described them as *Mentha palustris*, "peper mint". The well preserved specimens correspond in all essential characteristics with the peppermint which is to-day cultivated in Mitcham, county of Surrey, near London.²⁾ The cultivation of peppermint in Mitcham seems to have begun about the middle of the 18. century and was of some importance toward the end of that century. Up to 1805, however, the distillation of peppermint oil was not conducted in Mitcham but in London.³⁾

The English peppermint industry reached its height about 1850. From that time on American competition caused a decided setback in the production.⁴⁾ For purposes of distillation, peppermint was evidently not cultivated earlier on the continent than in England. According to the Leyden botanist David Gaubius, it was cultivated for this purpose near Utrecht in 1770. He also mentions the menthol, the *camphora europæa menthæ piperitidis*.⁵⁾ Meanwhile Linnæus had named the plant *Mentha piperita*.

About the same time peppermint was cultivated in Germany. Following the example of the London Pharmacopœia, in which peppermint was officinal since 1721 as *Mentha piperitis sapore*, it was mentioned in medical and botanical treatises. The treatise by Knigge⁶⁾ seems to have made it better known in professional circles.

In Japan, however, the cultivation of peppermint appears to antedate that of any other country. It is reported to have begun before the Christian period. According to Flueckiger, even menthol (*Hakuku*, *Hakka*) has been separated since that time and used

¹⁾ John Ray, *Historia plantarum*. London 1704. Vol. 3, p. 284.

²⁾ Flückiger, *Pharmakognosie*. 3. edition. 1891. p. 726.

³⁾ Lysons, *Environs of London*. 1800. p. 254.

⁴⁾ Chemist and Druggist 1891, 405.

⁵⁾ Hieronymi Davidii Gaubii *Adversariorum varii argumenti liber unus*. Leidæ 1771. pp. 99—112.

⁶⁾ Knigge, *De mentha piperitide commentatio. Dissertatio*. Erlangæ 1780.

as a remedy.¹⁾ According to Naojiro Inouye,²⁾ the words *Hakuku* and *Hakka* do not mean menthol, but peppermint. In the oldest medical treatise of Japan, the *Daiso-Rui-Shu-Ho* (806—809), peppermint is not mentioned. However, in the *Shin-J-Ho*, compiled by Tamba Yasuyori in 984, the plant is mentioned as *Megusa* (*Me* = eye, *gusa* = herb), of which an eyewater was made. When peppermint oil was first distilled in Japan is not known. The export of this oil began in 1873.

OIL OF EUROPEAN PENNYROYAL.

European pennyroyal (Ger. *Polei*) is derived from *Mentha pulegium*, L., (*Pulegium vulgare*, Mill.) or its hybrid varieties, and has been used medicinally since the middle ages³⁾ and possibly earlier.⁴⁾ The distilled *Oleum pulegii* is mentioned in the price ordinance of Frankfurt for 1582 and appears to have been used medicinally, like the plant and its distilled water, in the 16. and 17. centuries.

OIL OF SWEET BASIL.

Oil of sweet basil appears to have been in use during the middle of the 16. century. It is enumerated among the oils of the Frankfurt price ordinance for 1582 and in the *Dispensatorium Noricum* of 1589. The distilled water was used as early as the 15. century.⁵⁾

OIL OF VALERIAN.

During antiquity valerian was known as *Phu*. It is described in the writings of Dioscorides⁶⁾ and Pliny. Later it is mentioned

¹⁾ Flückiger, *Pharmakognosie*. 1891. p. 726.

²⁾ Bericht von Schimmel & Co., October 1908, Supplement.

³⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. p. 377.

⁴⁾ Pfeiffer, *Zwei deutsche Arzneibücher des 12. und 13. Jahrhunderts*. In *Sitzungsberichte der Wiener Akad. d. Wissensch.* Vol. 42 (1863), II, p. 137. (However, the possibility is not excluded that the *Poleiöl* mentioned here and in earlier treatises pertains to the oil of *Thymus Serpyllum*.)

⁵⁾ Hieron. Brunschwig, *Liber de arte destillandi. De simplicibus*, fol. 27.

⁶⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. I, pp. 20 and 348.

as a remedy by Isaac Judæus¹⁾ and Constantinus Africanus,²⁾ who are the first to use the term *Valeriana*. In a drug list of the Medical School of Salerno, *Phu*, *Amantilla* and *Valeriana* are mentioned as being identical.³⁾ In the 11. century, however, the name *Valeriana* appears to have been in use,⁴⁾ though the name *Phu* continued in literature as late as the 15. century.⁵⁾

During the middle ages the odor of valerian must have been a favorite for it was used for perfuming rooms, clothing and linen,⁶⁾ in like manner as the roots of *Valeriana celtica*, L., and those of *Nardostachys Jatamansi*, D. C., (*Nardus indica*) were used during antiquity.⁷⁾

How common the use of valerian root was in Germany becomes apparent from the large number of popular names and synonyms of which lists are given by the abbess Hildegard⁸⁾ in the 12. century, and by Hieronymus Brunschwig⁹⁾ toward the end of the 15. century.

The treatises on distillation of the 16. century provide directions for distillates of valerian with either water or wine.

The distilled oil was obtained by Hoffmann, Boerhaave, and Geoffroy, in part from the dry, in part from the fresh root.¹⁰⁾ Later Graberg (1782) described the oil,¹¹⁾ and Trommsdorff investigated the root in 1808.¹²⁾ In 1830 he named the acid obtained from the aqueous distillate valerianic acid.¹³⁾

¹⁾ Isaac Judæus, *Opera omnia*. Lugduni 1545. Cap. 45. "*Fu, id est valeriana, melior rubra et tenuis*".

²⁾ Steinschneider, in *Rohlf's Archiv für Geschichte der Medizin*. 1879. p. 96. "*Fu, id est valeriana; uaturam habet sicut Spica Nardi*".

³⁾ S. de Renzi, *Collectio Salernitana*. Alphita. 1854. III. pp. 271—322.

⁴⁾ Cockayne, *Leechdoms, Wordcunning and Starcraft of Early England*. 1866. III. 6, 136.

⁵⁾ Saladini *Compendium aromatariorum*. Bononæ 1488. Index.

⁶⁾ Turner, *New Herball*. 1568. Part. 3, p. 76. -- Langham, *Garden of Health*. 1633. p. 598.

⁷⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 7; and vol. 2, p. 348. -- Brunschwig, *Liber de arte destillandi*. *De simplicibus*. 1500. fol. 39 and 107.

⁸⁾ Hildegardis Abbatissæ *Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne. p. 1187.

⁹⁾ Brunschwig, *Liber de arte destillandi*. *De simplicibus*. 1500. fol. 39.

¹⁰⁾ Pfaff, *System der Materia medica*. Vol. 4 (1815), p. 172.

¹¹⁾ Lorenz Crell, *Die neuesten Entdeckungen in der Chemie* 6 (1782). 123.

¹²⁾ Trommsdorff's *Journ. der Pharm.* 18, I. (1809), 3.

¹³⁾ Trommsdorff's *Neues Journ. der Pharm.* 24, I. (1832), 134.

OIL OF NARDOSTACHYS JATAMANSI.

The rhizomes of *Nardostachys Jatamansi*, D. C., (*Patrinia Jatamansi*, Wallich) and of *N. grandiflora*, D. C., (*N. O. Valerianaceæ*) which are indigenous to the Himalaya mountains of northern India have an odor reminding faintly of musk but more strongly of patchouly. On account of its fragrance this root was highly prized during antiquity, being esteemed all the more because of its limited supply. It was used for perfuming ointments and fatty oils which were employed in anointing ceremonies. It was evidently regarded as one of the most precious aromatics.¹⁾ Later, especially out side of India, other roots were used as substitutes for the Indian narde (spikenarde), and frequently confounded with it, notably that of *Ferula sumbul*, Hook. fil., and still later that of *Valeriana celtica*, L.²⁾

The original Hebrew name was *Nerd*; in Greek (derived from the Sanskrit) it was termed *νάρδος*, *ναρδόσπικης*; in Latin, *Nardus indica*, *Nardus spica*, *Spica Nardus*; in Arabic *Senubol* (ear). Later this name was applied by different peoples to similar and even to different aromatic plants. Moreover, these were confounded with narde. In the first century of the Christian era, Dioscorides³⁾ already distinguished between *Nardus indica*, *syrica* and *celtica*. As *Phu*⁴⁾ he probably regarded partly narde, partly valerian.

¹⁾ Song of Solomon, 1:12; 4:13 and 14. — St. Mark., 14:3·5. St. John., 12:3—5. Horatii *Carmina*. Lib. IV, carm. 13, verses 16·17. During festive meals it was a Roman custom, not only to decorate guests with flowers, but to anoint them as well with narde.

*Cur non sub alta vel platano, vel hac
Pinu jacentes sic temere, et rosa
Canos odorati capillos,
Dum licet, Assyriaque Nardo
Potamus uncti.*

(Horatii *Carmina*. Lib. II. carm. 11.)

²⁾ Sir Wm. Jones, On the Spikenard of the ancients in "Asiatic Researches" In Transactions of the Society instituted in Bengal, for inquiring into the history and antiquities, the arts, sciences and literature of Asia. Calcutta 1789. Vol. 2. (London edition p. 416.) — Roxburgh, Additional remarks on the Spikenard of the ancients. *Ibidem* vol. 4, p. 97.

³⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, pp. 15--17.

⁴⁾ *Ibidem* p. 20.

As having a similar odor, Scribonius Largus¹⁾ enumerates *Nardus indica*, *Nardus celtica*, *Stœchas*, *Nardus italica*, *Spica Nardi* (also used to designate species of *Lavandula*), and Indian grass (species of *Andropogon*).²⁾

In mediæval literature the original narde is mentioned but once, namely as one of the precious incense materials used during the entrance of emperor Henry IV. in to Rome.³⁾ In mediæval treatises on distillation and in pharmacopœias, Indian narde no longer is mentioned, but *spica* and *spikenard* are.⁴⁾

OIL OF ELECCAMPANE.

Aqueous distillates of elccampane were used medicinally during the middle ages.⁵⁾ *Oleum radidis helenii* is first mentioned in the Frankfurt ordinance of 1582.

OIL OF ROMAN CHAMOMILE.

Owing to the similarity of some of the species of *Anthemis*, *Chrysanthemum* and *Matricaria*, it can not longer be determined which were cultivated by the Greeks and Romans and used by them. Nor is it possible to ascertain which species of the above genera is implied whenever *Anthemis* is used in the writings of Dioscorides,⁶⁾ Pliny, Tragus,⁷⁾ and other authors. According to Gesner,⁸⁾ Roman chamomile was introduced into France and Germany from Spain. *Anthemis nobilis*, L., however, received more consideration, in England, in the southern part of which

¹⁾ Scribonii Largi *Compositiones medicamentorum*. Editio Helmreich. Leipzig 1887. p. 72.

²⁾ See pp. 101, 184.

³⁾ Petrus d'Ebulo, *Carmen de motibus siculis*. Basiliæ 1746. p. 23. - Flückiger and Hanbury, *Pharmacographia*. 1879. p. 503.

⁴⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. fol. 72. See p. 195, footnote 2.

⁵⁾ *Ibidem* fol. 19.

⁶⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. p. 482.

⁷⁾ Hieronymus Tragus, *De stirpium maxime earum quæ in Germania nostra nascuntur commentarium libri tres*. Argent. 1552. fol. 149.

⁸⁾ Conradi Gesneri *De Hortis Germaniæ liber recens*. 1561. Fol. 253.

it was cultivated and used medicinally. Even during the 16. and 17. centuries the several chamomiles were not kept separate in literature, a condition that apparently also prevailed in practice.

Hieronymus Bock (Tragus),¹⁾ who lived during the first half of the 16. century, called the plant *Chamomilla nobilis*; whereas Joachim Camerarius, who lived during the second half of the same century called it Roman chamomile.²⁾ In the treatises on distillation of the 16. century the common chamomile seems to have been greatly preferred to the Roman chamomile.

On the continent, the latter was little used or not at all for medicinal purposes, whereas in England it was used almost exclusively as chamomile flower.

Side by side with *Oleum chamomillæ*, distilled oil of Roman chamomile was first mentioned in the drug ordinance of Frankfurt of 1587.

OIL OF GERMAN CHAMOMILE.

The common chamomile, *Matricaria Chamomilla*, L., was used medicinally by the Greeks and Romans, and is repeatedly referred to in classical literature.³⁾ It was also highly valued during the middle ages. Brunschwig⁴⁾ describes the distillation of the flowers.

The oil, which attracted attention on account of its blue color, seems to have been known since the middle of the 15. century. Saladin⁵⁾ mentions it in his list of medicaments of 1488, and the Nürnberg physician Joachim Camerarius⁶⁾ prepared it in 1588. Conrad Gesner⁷⁾ and Porta⁸⁾ distilled the oil after moistening the flowers with *aqua vitæ*.

¹⁾ See footnote 7, p. 196.

²⁾ Flückiger and Hanbury, *Pharmacographia*. 1879. p. 384. — Camerarii *Hortus medicus et philosophicus*. Francofurti 1588. p. 39.

³⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. p. 482—483. — Plinii *Naturalis historiae libri*. Lib. XXII, 26. Editio Littré. Vol. II, p. 82. — Palladii *De re rustica*. Editio Nisard. 1877. p. 608.

⁴⁾ Hieronymus Brunschwig, *De arte destillandi*. 1500. Fol. 38.

⁵⁾ Saladini Asculi *Compendium aromatariorum*. Venetii 1488. Index.

⁶⁾ Camerarii *Hortus medicus et philosophicus*. Francofurti 1588. p. 39.

⁷⁾ Eusebii Philatri *Ein köstlicher theurer Schatz*. 1555. p. 222.

⁸⁾ Gio. Battista Porta: *De destillatione*. Romæ 1608. p. 83.

In the price ordinances it is first mentioned in that of Berlin for 1574 under the title of *Oleum matricariæ*, and of Frankfurt-on-the-Main for 1587. In the *Dispensatorium Noricum* of 1589 it is mentioned as *Oleum chamomillæ vulgaris* besides *Oleum matricariæ*.

The blue color of the oil was attributed to a copper content due to the distilling vessels, until Pauli and Herford of Copenhagen showed in 1664 that the oil distilled from glass vessels likewise possessed a blue color.¹⁾ On a large scale, by steam distillation, chamomile oil was first distilled in 1822 by the apothecary Franz Steer²⁾ of Kaschau in Hungary. The oil was first examined by Zeller³⁾ in 1827.

OIL OF TANSY.

The distilled water from the flowers and leaves of tansy was a common remedy during the 16. and 17. centuries.⁴⁾ The oil is first mentioned in the price ordinance of Frankfurt-on-the-Main for 1582 and in the *Dispensatorium Noricum* of 1589.

The oil was first examined by J. Persoz⁵⁾ in 1841.

OIL OF WORMWOOD.

Wormwood is supposed to have been known to the Egyptians as early as the 16. century B. C.⁶⁾ In the Old Testament the plant is referred to repeatedly.⁷⁾ Whether the plant known to the ancients and later referred to as wormwood was the present *Artemisia absinthium*, L., or not can no longer be determined.

¹⁾ Simonis Pauli *Quadripartitum botanicum de simplicium medicamentorum facultatibus* etc. Argent. 1667. p. 425.

²⁾ Buchner's Repert. f. d. Pharm. 61 (1837), 85.

³⁾ *Ibidem* 25 (1827), 467.

⁴⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500. Fol. 94.

⁵⁾ Compt. rend. 13 (1841), 436; Journ. f. prakt. Chem. 25 (1842), 55, 60.

⁶⁾ Papyrus Ebers, Jahresbericht f. Pharm. 1880. 26. — Flückiger, *Pharmacognosie*. 1891. p. 686.

⁷⁾ Deut., 29: 18. — Proverbs, 5: 4. — Amos, 5: 7 and 6: 12. — Jeremiah, 9: 15; 23: 15. Lamentations, 3: 15 and 19.

In Greek and Roman literature wormwood received but little consideration; however, it is mentioned in the writings of Dioscorides.¹⁾ As a remedy, wormwood is praised by Walafrid Strabus²⁾ in the 9. century and by the abbess Hildegard³⁾ in the 12. century. From that time on it received occasional mention in pharmacopœias, but is wanting in most of the treatises on distillation of the 16. century, although known to their authors,⁴⁾ and even distilled by Brunschwig.⁵⁾

The distilled oil of wormwood was known to Porta,⁶⁾ who directed attention to its blue color. It was first examined by Fr. Hoffmann of Halle and recommended by him for medicinal purposes.⁷⁾ Later the oil was examined by Cl. J. Geoffroy,⁸⁾ by Fr. Kunzemüller,⁹⁾ by Buchholz,¹⁰⁾ and by Margueron.¹¹⁾ In price ordinances it is first mentioned in that of Frankfurt-on-the-Main of 1587, also in the 1589 edition of the *Dispensatorium Noricum*.

OIL OF COSTUS ROOT.

Costus root from *Saussurea Lappa*, Clarke, was known to the Greeks as *κίσθος*. During antiquity it was used as a spice, also in the preparation of a fragrant oil, for purposes of anoint-

¹⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, p. 367.

²⁾ Walafridi Strabi *Hortulus. De viribus herbarum*. Editio Choulant. 1832. p. 147.

³⁾ Hildegardis Abbatissæ *Subtilitatum diversarum naturarum creaturarum libri novem*. Editio Migne, *Patrologiæ cursus completus*. 1855. p. 1172.

⁴⁾ Conradi Gesneri *De Hortus Germaniæ liber recens*. 1561. Fol. 243.

⁵⁾ Hieronymus Brunschwig, *Liber de arte destillandi. De simplicibus*. 1500, fol. 112. — Brunschwig distinguished between the following species, viz., *Absynthium ponticum*, *Absynthium cretensis*, *Absynthium marinum*, used in the distillation of wormwood water. — See also Murray's *Apparatus Medicaminum* Göttingiæ 1766. Vol. 1, p. 118.

⁶⁾ Portæ *De destillatione libri IX*. Romæ 1608. p. 79.

⁷⁾ Friedr. Hoffmannli *Observationum physico-chemicarum selectiorum libri*. Halæ 1722. Lib. III. Observ. I, p. 9 and 355.

⁸⁾ *Mémoires de l'Académie des sciences de Paris*. 1721.

⁹⁾ Crell's Chem. Annalen 1784, 206.

¹⁰⁾ Götting's Almanach für Scheidekünstler und Apotheker 1786, 101.

¹¹⁾ Trommsdorff's Journ. der Pharm. 4, II. (1798), 202.

ment,¹⁾ similar to nard oil. It was also highly esteemed as remedy. Dioscorides²⁾ distinguishes between the white Arabian or Indian, and the black Syrian costus. Garcia³⁾ mentions that costus was used in Asia Minor, Syria, Arabia and Persia, but that it grows only in India. Costus root should not be confounded with *Costus dulcis*, a synonym for the bark of *canella alba*.

¹⁾ p. 195. W. Heyd, *Geschichte des Levantehandels im Mittelalter*. 1879. Vol. 1, p. 90; and Vol. 2, p. 580. - Dymock, *Materia medica of Western India*. 1885. p. 449.

²⁾ Dioscoridis *De materia medica libri quinque*. Editio Kühn-Sprengel. 1829. Vol. 1, pp. 15 and 29.

³⁾ R. Sigismund, *Die Aromata*. Leipzig 1884. p. 34.

IV. HISTORY OF THE METHODS OF DISTILLATION AND OF DISTILLING APPARATUS.

The literary documents considered in the previous chapter reveal the slow process of evolution leading up to a better understanding of the subject of volatile oils. In like manner, a short historical retrospect of the methods of distillation and distilling apparatus may result in an insight into the gradual development of the art of distillation and of the methods of preparation of distilled oils. The history of the evolution from the primitive *Cucurbita*, the *Alembic* and the *Berchile* to the steam and vacuum apparatus of our own time reveals a long and varied course which had to be traversed by this apparently modern branch of industry in order to bring it to its present technical and scientific perfection.

As is well known, primitive man regarded fire as something supernatural. Thus the Greeks believed it to be the gift of Prometheus and used it accordingly in their religious rites. The oldest tribes of the Persians worshiped it as a divine element. A more practical use was made of it by the Chinese, who in the remotest antiquity utilized it in the development of a most remarkable, though primitive industry. The oldest books of the Bible report that Tubal-Kain was "an instructor of every artificer in brass and iron";¹⁾ they also state that bricks were burnt²⁾ for the construction of the tower of Babel. According to the apocryphal document, the *Ayur-Vedas*,³⁾ the Indians at an early date not

¹⁾ Genesis, 4:22.

²⁾ Genesis, 11:3.

³⁾ See p. 16.

only used furnaces for melting and firing, but also for distillation. They were used extensively by the Egyptians during their long and highly developed period of civilization.

For more than ten centuries, from the time of the Arabians to the end of the middle ages, the solution of minerals, of vegetable and animal drugs with the aid of furnaces was regarded as a noble and "subtle" activity in the search for the philosopher's stone. This philosopher's stone was not only to serve the purpose of converting baser metals into gold, but also of preparing a *quinta essentia* for the maintenance and reestablishment of health and the prolongation of life. Hence the furnaces, apparatus, and implements constructed for the practice of the hermetic art and for alchemistic purposes are important, not only for their own sake, but as essential aids to technology. They afford an interesting illustration of the desire to solve the problems of a better knowledge of natural objects in so far as it can be gained by the direct or indirect action of heat as generated in the several types of furnaces used since antiquity. Thus the furnaces constructed for melting and sublimation were used in the search for the *lapis philosophorum*, the latter together with the furnaces used for distillation in the search for the *quinta essentia* of organic nature. As a final hypothesis, the doctrine of phlogiston was developed in the long epoch of practical endeavor and theoretic speculation. With its overthrow there were also abandoned at the close of the 18. century the beliefs in the miraculous, and the prevailing doctrines of the elementary nature of natural objects.

The first definite statement found in ancient writings which indicates a kind of primitive distillation, although probably not illustrated until the middle ages, is the mention of the method for obtaining oil of cedar, *αισκήλιον* (turpentine oil?), which occurs in the writings of Herodotus, Dioscorides and Pliny.¹⁾ This oil is said to have been obtained from the oleoresin by boiling with water in an open earthen kettle. The oil either collected at the surface of the liquid and was removed, or its vapors were con-

¹⁾ Herodoti *Historiæ*. Lib. II, 85. -- Dioscorides, *De materia medica*. Lib. I, 34, 39, 80. Plinii *Historia naturalis*. Lib. XV, cap. 6-7; and Lib. XVI, cap. 22. *E pice fit, quod pissinum appellant, quum coquitur, velleribus supra habitum ejus expansis, atque ita expressis . . . color oleo fulvus.*

densed in layers of wool spread over sticks of wood laid cross-wise on the kettle as illustrated in figure 4. The wool when saturated was replaced from time to time by fresh portions and the oil expressed with the hands.

Authentic representations of the distilling vessels used by the Egyptians do not exist.¹⁾ Some of their forms of apparatus were undoubtedly adopted by the Arabians and improved by them. To the oldest known writings which give information on methods of distillation and distilling apparatus belong those of the Greek physician Dioscorides²⁾ who lived during the first century of our era in Anazarbus, Sicily, and those of the Greek philosopher Zosimos³⁾ of Panopolis. In a Arabian manuscript translation of Dioscorides' *Liber de materia medica* in the library at Leyden, distilling furnaces and apparatus are mentioned and described. These descriptions probably occur in the original Greek text. Among them are found the *cucurbita* and the *alembic*.⁴⁾



Fig. 4.

Just as pictures of animals have served as symbols in the oldest mythology of and as characters in writing by the earliest peoples, the forms of animals were used by the ancients as prototypes in the making of jewelry, and of all kinds of useful articles and apparatus. The same practice appears to have obtained in the making of

¹⁾ Egyptian and Greek distilling apparatus of the 3. and 4. centuries, which served primarily for the distillation of mercury, have been reproduced in Dujardin's *L'art de la Distillation*. Paris 1900. These illustrations were found in a manuscript of the end of the 10. century in the Marcus library in Venice and are copied from Berthelot's *Introduit. à l'Etude de la Chimie des Anciens et du Moyen-âge*. 1889.

²⁾ See p. 19.

³⁾ *Περὶ ἀργύρου καὶ καμίνων* (of apparatus and furnaces). See p. 22.

⁴⁾ Extracts from this as well as from the later Arabic texts of Rhases, also an unimportant illustration of an Arabic distilling apparatus, have been published by Prof. E. Wiedemann in vol. 32 (1878), p. 575 of the *Zeitschrift der deutschen morgenländischen Gesellschaft*.

primitive digestion and distilling vessels. Such pictorial representations have been carried over from the writings of Zosimos, and probably of others into the writings of the Arabians and from these into other alchemical works of the middle ages.¹⁾

As the prototype of a common flask, the figure of an ostrich²⁾ is given (fig. 5); as that of a retort a goose (fig. 6) or a pelican³⁾ (fig. 7). The

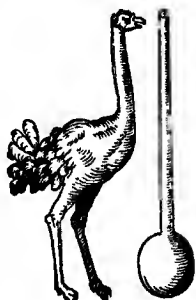


Fig. 5.

shape of a bear served for a still (*cucurbita*)⁴⁾ and head (*alembicus*) (fig. 8). An improved form of this simple distilling apparatus is found in the writings of Geber,⁵⁾ and of Albucasis.⁶⁾ The latter not only described glass distilling vessels, but also those



Fig. 6.



Fig. 7.

prepared of glazed earthenware (fig. 9). He also described a kind of fractional distillation for the purpose of a "better con-

¹⁾ Joannis Rhenani, *Medici, Solis e puteo emergentis: sive dissertationis chymia technice practica, materia lapidis philosophici et clavis operum Paracelsi, qua abstrusa implicantur deficientia supplentur*. Francofurti 1613. Pars 1. *Theoremata chymio technica*.

²⁾ *Phiala est vas vitreum ex ventre in modum sphaerae rotundo gracilem canalem in proceritatem emittens.*

³⁾ *Pelicanus est vas circulatorium e figura pelicani pectus suum rostro lodientis, pullosque suos refarcientis nuncupatum, amplo ventre sensim in angustiis collum vergente, quod retortum et curvatum os rursus in ventrem immittit.*

⁴⁾ *Cucurbita est vas plerumque turbinatum, in cucurbitae vel pyri formam utero turgescens. Cucurbita cum suo alembico juncta ejusmodi est.*

⁵⁾ Gebri *Sunima perfectionis magisterii*. Gedani 1682.

⁶⁾ See p. 25.

densation and separation of subtle spirits" by placing several *alembices*¹⁾ on top of one another (fig. 10).

From the writings of Geber and Albucasis, also from those of the excellent physician and writer Rhases (*El Râzi*) who lived in Bagdad during the 9. century, it becomes apparent that the Arabians distinguished as early as the 8. century between

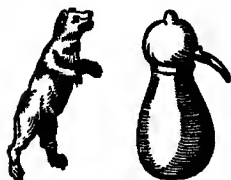


Fig. 8.



Fig. 9.

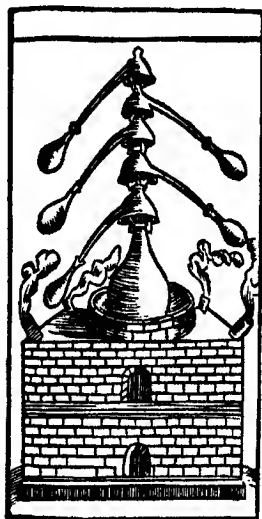


Fig. 10.

distillation over an open fire and from a water bath and an ash bath.²⁾ Geber described both methods in detail.³⁾

For the purpose of better condensation, Costæus of Lodi,⁴⁾ a physician and alchemist of Bologna, recommended that the

¹⁾ *Liber servitoris* Bulchasin-Ben-aberazerin. Venetiæ 1471. Lib. XXVII, p. 247. *Modus alius cui vult destillare paucam aquam. Accipe ollam ex ære, et imple eam aqua, et pone super lanem ignis, et pone os ejus coopertorium perforatum foraminibus duobus vel tribus vel pluribus, aut paucioribus ventribus secundum quod poterit capere coopertorium ollæ, et sint ventres ex vitro . . .*

²⁾ *Das Buch der Geheimnisse des Abû Bekr Ben Zakarijâ Er-Râzi*. Fleischer's Katalog No. 266. Leipziger Stadtbibliothek. Codex K. 25.

³⁾ *Gebri Summa perfectionis magisterii*. Cap. 50. *Ex bibliotheca vaticana exemplari*. Gedani 1682.

⁴⁾ *Mesue, Simplicia et composita, et antidotarii novem posteriores sectiones adnotationes*. Venetiæ 1602.

beak of the alembic be cooled by water (figs. 11 and 12), also that the distillate be improved by the use of the water bath (*balneum Mariæ*) (fig. 13) and the sand bath (*balneum arenæ*) (fig. 14).

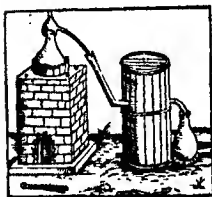


Fig. 11

Among the writings left by the Arabians, the work of Albucasis previously mentioned probably contains one of the first and most striking descriptions of the manner of distillation and distilling apparatus.¹⁾

From the 14. century on the practice of making distilled liquors increased very considerably. As a result the methods of distillation and the distilling apparatus, especially those parts employed for the condensation of the vapors, were greatly improved. The method of condensing the vapors, already well known to the Arabians,

by passing the straight or bent tube of the alembic, or an elongation thereof wound into a spiral (wormtube, *serpentina*) through a tub of cold water was already in general use at that time for the distillation of wine and fermented plant juices. As examples of such distilling apparatus and methods, "*die mancherley Kühlungen der Teutschen und Welschen Weinbrenner*", are described and illustrated in treatises on distillation of the first half of the 16. century, namely in those of Brunshwig, Ulstad, Ryff, and Lonicer. In these a distilling apparatus constructed with considerable skill is described. The

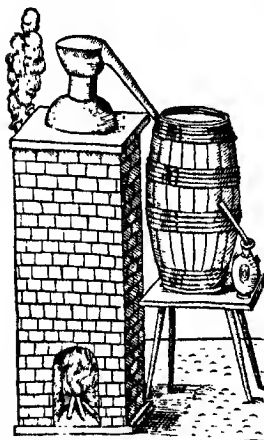


Fig. 12.

helmet of the still and the outer condenser jacket were made of sheet copper. The head-like form of the expansion of the helm with the outer jacket, the lower open rim of which was tightly

¹⁾ See p. 26.

luted to the still, gave rise to the name of *Mohrenkopf*. The condensation was effected by a continuous flow of cold water through the outer jacket (fig. 15).

The method of condensation derived from the Arabians was considered the most perfect for the distillation of spirit of wine (*aqua vitæ*). The illustration of this apparatus was selected for the title page of the second volume of Brunschwig's *Destillirbuch* published in the year 1507 and is reproduced on page 41. Where the two upright serpentine connecting tubes (*serpentinæ*) between the retorts (*cucurbitæ*) and the receivers (*receptacula*) cross each other they pass through a condensing tube filled with cold water. The cooling effect thus produced is not sufficient for the condensation of all the vapor. The worm acts therefore, as a dephlegmator and increases the alcoholic strength of the distillate. This is correctly emphasized by Brunschwig.

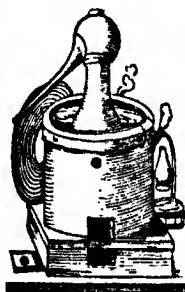


Fig. 13.

diweil die Geister, so über sich getrieben werden, vil reyner und subtiler seind, denn in solchem aufsteigen alles, so schwer, indisch oder flegmatisch ist, nit hinauf kommen mag. Darumb die Geyster des weins am flüchtigsten über sich, aber anderer materi, so mehr mit flegmatischer feucht behafft, under sich getrieben werden.¹⁾

The perfection of the apparatus for the preparation of distilled waters and oils, which up to that time had received but little attention, seems to have progressed much more slowly and with greater difficulty. In comparison with the readily volatile alcohol, water was considered as that product of distillation most closely related to it, whereas the oil was regarded as the "obese and fatty substance that had to be driven over with a stronger and more violent heat." This had led to the firmly established belief that in the process of purification the volatile and



Fig. 14.

¹⁾ Hieronymus Brunschwig's *De arte destillandi*. Vol. 2, liber 1.

subtle part must penetrate and exhaust the material as much as possible (resolving). As a result all sorts of queer apparatus and sources of heat were invented for producing the so-called circulation. They all resulted in a prolonged digestion and an unintentional loss of the alcohol, oftentimes formed by fermentation, and of the aroma.

Circulation was therefore considered not only as the essence of distillation, but also as an important preparatory part of it. It

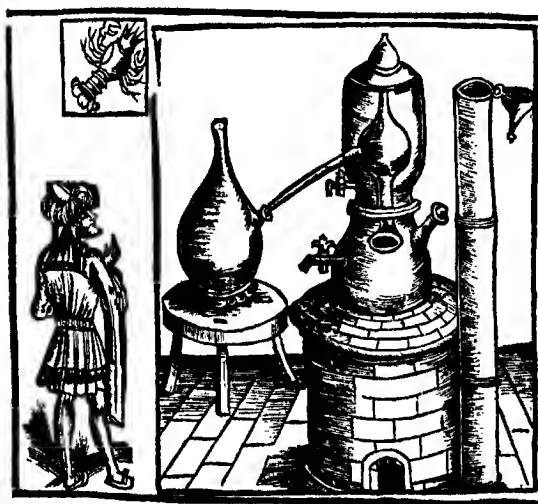


Fig. 15.

was believed that the plant and animal material finally to be distilled was thereby prepared for the refinement and purification of the spirit beings ("geistige Wesen") contained in them, and for their better and easier separation and purification. A large variety of vessels, usually constructed after some symbolic prototype, was used for this purpose. The simple *Circulatoria* were ordinary glass flasks, retorts the tubes of which were bent in a variety of ways, also so-called urine glasses used by physicians for diagnosis.

The operations performed in the pelican (fig. 16) and double or twin *Circulatoria*¹⁾ (fig. 17) provided with reflux tubes were considered as the most perfect kinds of circulation, especially for refining the "spirits."

Still more peculiar than the form of the *Circulatoria* was the source of heat used for the purpose of circulation, which was usually accompanied by fermentation, and even decomposition processes. Not only was the water bath (*balneum Mariæ*) (fig. 18) and the ash bath (*balneum per cinerem*) (fig. 19) employed, but also the sun bath (*destillatio solis*) (fig. 20). The circulation vessels were also immersed in fermenting dough, and heated with this in an oven (*destillatio panis*); or they were



Fig. 16.

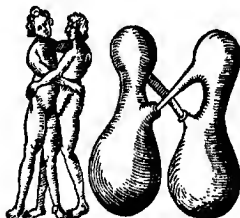


Fig. 17.

imbedded in decomposing, well wetted horse manure which was placed in a layer above unslaked lime in pits (*destillatio per ventrem equinum*) (fig. 21).

With the introduction of aromatic waters as one of the principal forms of medication, the condensation of the vapors gave rise to difficulties, because a greater degree of heat was necessary for their distillation. Plant material lying on the bottom of the still was also easily burnt, and the distillate received therefrom an empyreumatic odor and taste. With a strong heat a serious overheating of the helm and tube, which were usually constructed of lead or tin, took place, while with the employment

¹⁾ *duota est vas circulatorium a duabus auribus, vel viro utrumque brachium lateribus applicatum habente, dictum, hujus inferior pars est in modum cucurbitæ, cui impositus est alembicus in summo canalem habens; in loco autem conneviente duobus rostris incurvatus et in cucurbitam a capitello humorem, condensatum ducentibus præditum.*

of a moderate heat the yield of the distillate remained unsatisfactory. In order to overcome these disadvantages, and to prevent the flowing back of the distillate condensed in the helmet, as well as to increase the cooling effect of the air, the helmet known as the "Rosenhut" (fig. 1, p. 40 and fig. 22) was constructed as early as the 15. century. Near its base, at about the height of the



Fig. 18



Fig. 19

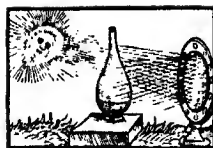


Fig. 20.



Fig. 21.

outlet tube, a groove extended around the inside of the helmet. Through this the water, condensing on the upper inner wall of the helmet and running down, was conducted into the outlet tube and from there into the receiver. The "Rosenhut" was therefore in itself an inefficient air condenser, which served its purpose with much less efficiency than did the "Mohrenkopf" in the distillation of alcohol (fig. 15, p. 208).

In the preparation of the distilled waters, the first step toward a better condensation with cold water, consisted in surrounding the head of the helmet (*alembic*) with an oxbladder.

It was securely fastened and provided with a wooden stop-cock. The hood-like basin thus formed (fig. 23) was kept cold by means of flowing water. In a similar manner the helmet was also surrounded by a basin-like metallic addition which was either fastened by luting or soldering. Thus the helmet could be well cooled by running water (fig. 24). By means of an inner horizontal groove like that in the "Rosenhut" (fig. 22) the distillate



Fig. 22.

which condensed on the inner walls of the helmet was conducted into the receiver.

About the middle of the 16. century, Walter Ryff in his treatise on distillation¹⁾ describes and illustrates distilling apparatus with condensing tubes which are passed through vessels of cold water. The first apparatus has two tubes, connected with the helmet (fig. 25), which are passed through a barrel of water. However, Ryff declares this method of condensation as insufficient and recommends a worm tube, for the shape of which

¹⁾ See p. 46.

he gives two forms (figs. 26 and 27), and concerning the use of which he gives the following account.

Die Spiritus sollen durch sonderliche Instrument recht digerirt oder gekalt, und von der unmessigen hitz und erbrennung solcher geyster abgezogen werden, als nemlich mit den rören so mit vilen krümmen durch ein wasser geht, von irer seltsamen krümme wegen Serpentina genannt, das ist Schlangenrör. Solcher rören empfahen die erhitzigten geyster, so von der wärme aufgetrieben werden, und föret sie durch die vile krumh lini, und wider durch das wasser damit sie genügsamlichen gekilet werden Zu einem Destillations-geräthe nit allein in der Abstraction der spiritus oder geyster, sondern auch zu mancherley Destillation, als nemlich der Emacerirten oder wol erhitzigten, Purificirten oder Dirigirten Weckholderheer, Stickschlimmen, Spic, Lawendel, und anderei dergleychen öliger, hitziger und



Fig. 23



Fig. 24

feyster gewechs und Wurzeln, von welcher wir das oel abzichen wollen, darumb schaff die ein küpflein oder irdin kessel zu Destilliren durch den dampff des hitzigen Wassers. Auf diesen kessel lass dir einen helm bereiten von guter erden, innerhalb und ausserhalb wol verglasurt. Dieser helm sul sich auf den kessel wohl schliessen, also dass es nit möge ausriechen. . . . Dieser helm sol oben ein loch haben, darin du die rören oder Serpentine stecken, und auch auf das best vermachen mögest, welches Serpentin durch ein wasser gericht sol werden, das allezeit kalt sei, damit die geyster, so fast rein und subtil, ganz leichtlich zu verhitzigt und verbrennt werden, on underlass külung und erquickung empfahen. Solch Serpentin magstu nach mancherley art und

manier bereyte, also dass die geyster under sich oder ober sich getrieben werden.¹⁾

A peculiarly constructed apparatus for the distillation of aromatic waters and oils was recommended by Adam Lonicer in his *Kräuter- und Destillirbuch* published in 1573. Offenbach's translation of the description is as follows:

Von Gewürzen und allerhand Saamen, als von Nägelein, Zimmet, Muskatnuss, Anissamen, Römisch Kümmel, Wisskümmel, Fenchelsaamen und dergleichen, kann man mancherley edle und köstliche Öle abziehen. Und dieweil solche Öle nun sehr gemein im Gebrauch seien habe ich die Form und Weise der gemeinen Instrument und Ofens, sammt der Destillation,

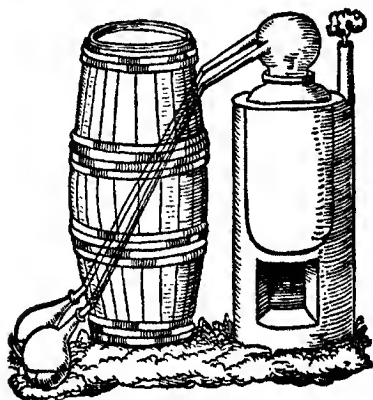


Fig. 25.

hiebe! gesetzt (fig. 28). Man bereitet einen gemeinen Destillierofen, wie zu einem einfachen balneo Mariæ pflegt gemacht werden, darin setze man ein kupffern Blase so ziemlich grosz ist, dass sie eine gemene Masz oder sechs haltet. Solcher Blasen Hals oder Mund sol oben handbreit weit sein, und über den Ofen herausgehen. Darauf! stürztet oder decket man ein kupffern Hut, so wol darin einschliesset. Solcher Hut soll oben ein Rörlin haben so eines Fingers dick weit ist und eines halben Fingers lang über sich gehet. Daran steckt man die blechen Rören, so uff die art, wie folgende Figur aussweiset, bereitet sein, dass sie gehet in ein andern kupffern Kolben, so auch einen Hut mit einem Rörlin oben hat. Darauf! setzet man ein andere auch dergleichen blechen Rören oder Serpena in welche durch ein Vasz, in ein Füllerglas, darin die destillirte Materie liisset, ausgehet.

¹⁾ W. Ryff, *New gross Destillirbuch, wohlbe gründeter Destillation*. Frankfurt a. M. 1567. Fol. 21.

So man nun von Gewürtze oder von Samen die Olea distillim will, sol man die kupflern Blase so in dem Brennolen stehet halh vol Brunnenwasser lüffen, und darnach die Gewürtze oder Samen, darvon man die Olea abziehen will, wol zerstossen, derselben ein Pfund oder zwei darin thun. Die Instrument oder Rören an allen Orten, da sie zusammen gesteckt werden, wol gehah mit Ochsenblasen und Meef verwaren, und das Feuer under-

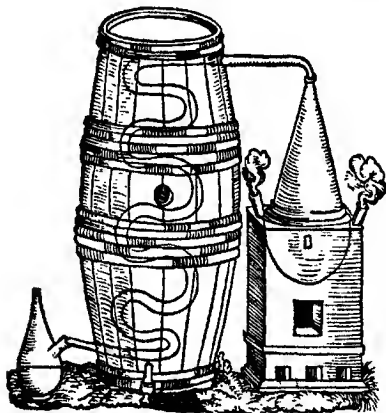


Fig. 26.

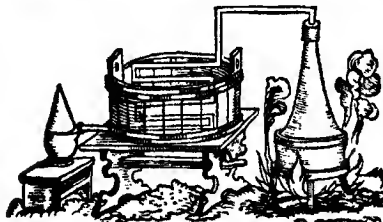


Fig. 27.

machen. Erstlich sanfft und darnach je lenger je heftiger regieren. Solche Distillation gehet geschwind nader, in drei oder vier Stunden. Wann nun die beste Spiritus also herausz gellieszen und abgelauffen sein, sol man das Oleum so oben in dem Glasz schwimmt, sauter darvon in ein he-sonder Gläszlin geschicklich ahsondern.¹⁾

¹⁾ Adami Loniceri Kräuter Buch und künstliche Conterfeyungen sammt der schönen und nützlichen Kunst zu destilliren. Von Petrus Uffenbach in's Teutsche übertragen. Ulm 1703. pp. 18—19.

Finally, the Arabians and probably others before them practiced "downward distillation" which corresponds on the whole to our modern dry or destructive distillation for obtaining empyreumatic or tar oils. At the time of the revival of the distilling art, this method was also applied to the preparation of the oils of certain woods, barks and spices. Juniper wood in particular had been submitted to this *destillatio per descensum* since

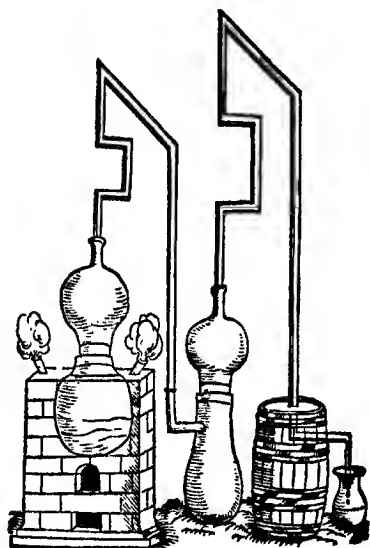


Fig. 28.

antiquity, later also guaiac wood, cinnamon, cloves, mace and other spices were distilled in this manner. The furnace contained a division in the middle, with a central opening into which a pot, provided with a back-like opening at the bottom, was either hung or plastered in. On top of the opening extending into the upper part of the furnace was placed a wire gauze and a second pot filled with the dry substance to be distilled was luted with its opening on the top of the lower pot. The heating was then effected by building a fire around the upper pot (fig. 29). Some-

times the lower pot was buried in the earth and a fire built about the upper pot fastened on top of this one in the same manner.

For the *destillatio per descensum* on a small scale, glass vessels heated from the side (fig. 30) were also employed, and for some easily distilled substances even the heat of the sun (*destillatio solis*) (fig. 31) was used. At present the preparation of empyreumatic oils as well as of the finer tars is effected in cast iron or earthenware cylinders.

Titles, such as *de lurnacibus construendis*, as well as illustrations of some of the older treatises, already enumerated, reveal that no little attention was given during the middle ages

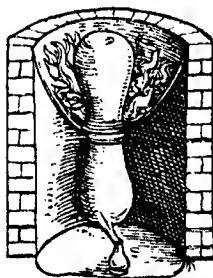


Fig. 29



Fig. 30

to the construction of distilling furnaces. Abundant evidence thereof is found in the 16. century treatises on distillation. Besides the distilling apparatus most generally used at that time, and reproduced in figs. 11, 12, 15, 18, 22, 24, 25 and 26, the so-called *laule Heinz* or *Athanor* (from *ἀθάνατος*, imperishable), called *lurnus Acediæ* by Ulstadt (fig. 32), was much in favor and was used to a great extent for the distillation of waters and oils. Above a common fireplace were placed three or more distilling retorts with *Rosenhuthelm* (p. 211, fig. 22). The fireplace ended in a central iron, copper or earthenware pipe, the opening of which could be closed by a cover. By means of slides at the sides of the fireplace the heat could be conducted under any one of the stills or retorts as desired, and the distillation was thus regulated.

For the distillation of large quantities in a large number of individual retorts or stills, larger cupil furnaces after the manner of the so-called "galley furnaces" appear also to have been in use. The illustrations and descriptions of these in some of the treatises on distillation of the 16. century represent no doubt

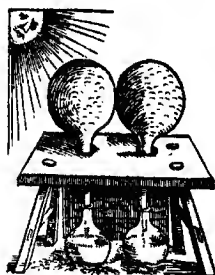


Fig. 31.

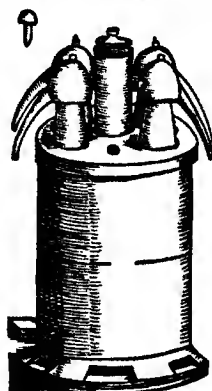


Fig. 32.

more the possibility than the realization of perfection. The illustrations of these furnaces were transferred from one distilling

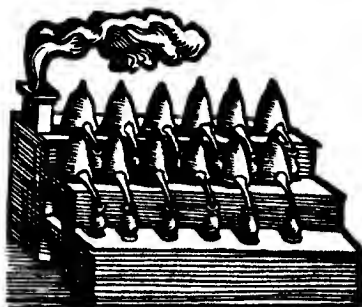


Fig. 33.

book to another, but the furnaces themselves probably have not been generally used in practice. Among others they are thoroughly described in the text and reproduced by illustrations in the works of Matthiolus and of Lonicer previously mentioned. They are built either in the shape of a terrace (fig. 33), or of a

bee hive (fig. 34). Matthiolus describes one of the latter type, in which the retorts are placed between the tiles, and its mode of operation in the following words:¹)

Ultima hac fornace utuntur Veneti ac Neapolitani, qui vitreis alembicis abundant. In aqua una tantum die et nocte, sicco ignis calore, eliciunt quæ ultra centum libras. Fornax rotunda est, ut ex imagine hic appicta apparet, fornacibus, quæ in Genuanorum visuntur vaporariis, omnino similis. Continet hæc circuncirca numerosa fictilia, intrinsecus vitro incrustata, urinalis formæ referentia et diligente sane artificio argillaceo luto agglutinata, quibus singulis per rotum fornacis ambitum singuli adduntur vitrei alembici, e quorum vertice ex globulo ad hoc parato, recipientia crassiusculo foniculo ad alligata, pendent. Calefit hæc fornax eodem modo, quo Germanicorum vaporariorum fornacis. Atquedum ignis vehemens est, vacua relinquunt vasa, donec parumper remittatur, ne violente calore plantæ et flores exurantur. Tunc itaque plures ministri, qui hoc tantum artificio duntur, obstructo undique fornacis ostio, ne conclusus expiret calor, herbas fictilibus injiciunt, et simul vitreos applicant alembicos. Atque in hunc modum copiosas eliciunt aquas et olea, quæ longe meliores habeantur, quam quæ plumbeis emulciuntur instrumentis, quod nullam metallorum contrahunt infectionem.

Although the compilers of the distilling books of the 16. century have successively followed the pioneer work of Brunschwig, especially in regard to illustrations, their writings nevertheless quite often show considerable differences in views, practical skill, and experience, and also in the originality of their knowledge and ability. With but little public intercourse these secluded workers and writers toiled mostly far from one another, each in his own sphere and manner, often with but a slight knowledge of the older writings and of the work of his contemporaries. With regard to the manner of distillation of the aromatic waters and oils, this is shown in an unmistakable manner in works compiled in the course of the first half of the 16. century by Philipp Ulstad, Walter Ryff, Adam Lonicer, Valerius Cordus, and Conrad Gesner. All of these were mainly based on the writings of Hieronymus Brunschwig. Their views, however, as to the nature of distillation itself and of the distilling methods and apparatus are neither in accord with those of Brunschwig, nor with those of their contemporaries.

¹) Petri Andreae Matthioli Opera quæ extant omnia. Supplementum: De ratione destillandi aquas ex omnibus plantis: et quomodo genuini odores in ipsis aquis conservari possint. Basilæ 1565. p. 5.

How little personal skill, practical experience and familiarity with the literature on the subject may be found in the writings and methods of working of the most prominent experimenters of that time becomes apparent *e. g.* from the construction of

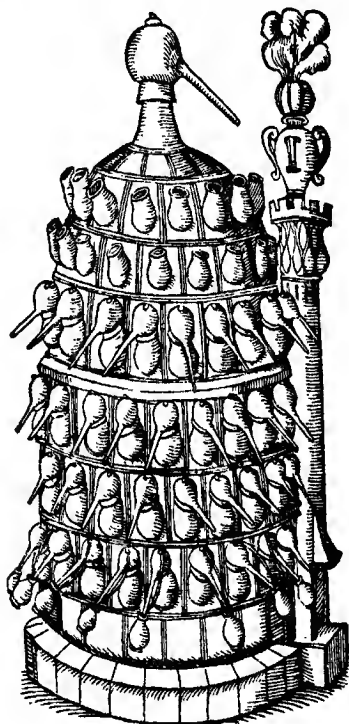


Fig. 34.

and preference for the distilling vessels employed. Thus for instance, Valerius Cordus,¹⁾ profound in theoretical science, but ignoring the rationally constructed distilling apparatus then well known, used and recommended *ein Kolb mit einem ange-*

¹⁾ Valerii Cordi *Annotationes in Pedacei Dioscoridis de Materia medica libros quinque. Liber de artificiosis extractionibus. Liber II. De destillatione oleorum.* Anno dei 1540. p. 229.

schmelztem Helm (fig. 35) as an efficient apparatus meeting all the requirements of the art. At the same time Conrad Gesner,¹⁾ his contemporary, used for the same purpose a distilling furnace (fig. 36), which had long been in use.

How confused were the ideas as to the nature of the distillation of the volatile oils even on the part of a man like Gesner who was theoretically and practically equally well trained, becomes apparent from the following extract of Gesner's description of the preparation of distilled oils and of spirit of wine from wine.

Die Specerey (Nelken, Muscatnuss, Safran, Macis, Benzoe, Myrrha, Storax etc.) wird groh gepulvert, dann mit aqua vitæ durchfeuchtet und bei gelinder Wärme destillirt . . . wenn das Öl anfehlt zu fliessen, so nimm die materi der specereyen aus dem Kolben und thut in ein säcklin, welches wohl verhunde sye mit einem ladeu, und trucks aus under einer prässen. Also dass der heide hñch der pressen wohl heiss machest. Und also gebührt es sich das angetruckte öl zu destilliren, rectificiren und circuliren, damit auff diese weis das rein lauter öl werde geschieden von der grohen yrdischen materi. Demnach mag man wol wiederum die häpfen putrificiren und digeriren mit dem vorgemelten aqua vitæ, so von anderen abgesünderet worden. Unn zum letzten wiederum destilliren.²⁾



Fig. 35

The operation was interrupted at the beginning, the fatty oil saturated with ethereal oil expressed, and the volatile oil remaining in the residue separated by distillation.

For the distillation of the volatile oils from flowers, Conrad Gesner gives the following directions:

Die Blüten der Spiken oder des Lavauder solt du eine kurze Zeit lang sonnen in einer grosen gläseinen retorte und darnach ein Wasser in einem alembik darvounen destilliren und abziehen. Dieses Wasser durch den ganzen Sommer gesetzt an eine warme statt an die Sonnen, so treyht es lür und für öl über sich, welches öl du alhwägen solt von dem wasser separiren und absündern mit einem fäderlich (feathervane) und dasselbe fleyssig halten in einem gläseinen guttern (flask) wohl vermachet und verstopfet.³⁾

¹⁾ *Thesaurus Eponymii Philatri, Ein köstlicher Schatz etc.* Zürich 1555. Fol. 216. "Wie man möge Oel separiren und abziehen von den Specereyen, Blüten und Samen". Edition of 1583. p. 206.

²⁾ *Thesaurus Eponymii Philatri, Ein köstlicher Schatz etc.* Zürich 1555. Fol. 215—237.

³⁾ *Ibidem* fol. 222.

According to Gesner, anise and other umbelliferous fruits are to be bruised and macerated with wine (fol. 227) before being distilled. Juniper berries are distilled *per descensum*, and the empyreumatic oil thus obtained rectified by *destillatio per ascensum* (fol. 231).

As an illustration of the crude views held as to the nature of distillation, and as to the products of distillation, the directions for the rectification of spirit of wine given by Ulstad¹⁾ and followed by Gesner²⁾ may here be quoted:

Wann weyn zwey oder drey mal fleyssig und ordentlich destillirt sein wird, so nimm einen reinen und dunnen Schwamm und zerhauwe denseligen in so grosse stück, welche in der grösse sygend, dass sy oben für an allen orten inwendig der kolbensmogind anrühren. Der selbig schwamm sol angehenden werde und mit zweyen oder dreye schnürlinien, welche für den kolbe hãrausreichend, damit so du demnach einen helm darauf setzest, die schwämm nit mögind an hoden des destilliergefesses fallen, und dieselhigen schwämm söffend vorhin in haumöl gesetzt werden, und demnach wiederum ein wenig ausgetruckt, damit nicht etwan das haumöl in den kolben herabtrieffe, und der materi so man zum destilliren genomme hat, vermischet werde und wann du jin also thon hast, so setz ei helm darauff welcher allenthalben verstriche seyge, damit kein dampff nirgends heraus gan möge. Und durch diesen schwamm werdend die aufgetriebenen geyster des aquæ vitæ simplicis seer wäsentlich und feyn destilliert. Also was groher unreiner, yrdischer und ungedünwter materi und substanz ist, mag von wägen dess öls nicht durch den schwamm gan und durchdringen. Und so du den gebrannten weyn auff diese weys und art zu destillieren zu hand nimbst, so wirst du mer in einem ahzug schaffen, dann sunst in dreyen.



Fig. 36.

As has already been mentioned, the 17. century, crippled as it was by the destructive storms of the Thirty Years war, added but little to the further development of the art of distillation and other technical scientific industries. The few active experimenters, however, favored with a better understanding, endeavored to perfect not only the apparatus used, but the processes as well. As the *Destillirbuch* of Brunswick and similar treatises of his successors reflect the practical and theoretical knowledge

¹⁾ *Caelum Philosophorum seu liber de secretis naturæ*. Argentor. 1528.

²⁾ *Thesaurus de remediis secretis*. Vol. 1, fol. 68. Tiguri 1552.

of the 16. century with its mistakes and imperfections, so Rudolph Glauber's¹⁾ treatise on distillation reflects the condition of the art and science of distillation during the second half of the 17. century. Although Glauber's laboratory work and the character of his writings was of a wider scope than that covered by the older treatises on distillation, yet he also paid special attention to the distillation of aromatic plants and spices. In this, he and his contemporaries seem to have paid special attention to the improvement of the methods of distillation for the purpose of relatively increasing the products of distillation. For this purpose, as has already been mentioned on page 65, a very rational expedient of increasing the specific gravity and thus raising the boiling point of the water used for the distillation, was resorted to. It was effected by the addition of salts. A peculiar method for the distillation of volatile oils with the addition of muriatic acid is described by Glauber in the following words.

Fülle einen gläsernen Kolben voll mit Cinnamonum oder anderem Holz, Samen, Macis etc. und giesse darauf so viel Spiritus salis,²⁾ dass es das lignum bedecke, setze solchen mit einem alembic in das Sandbad, gieh Feuer, dass der Spiritus salis kochet, so steigt mit wenig phlegmate alles Öl über, denn der Spiritus salis durchdringet wegen seiner Schärfe das lignum, macht das Öl ledig, dass es desto lieber übersteiget. Also wird auf solche Weise das Öl nicht wegen grosser Menge des Wassers verschmieret und verlohren sondern in kleinen Gläsern mit wenig Wasser aufgefangen und separiret . . . Auf solche Weise mit dem Spiritus salis kann man aus allen theuerbaren Vegetabilibus ihr liebliches Öl mit Nutzen machen. Desgleichen können auch alle Gummi und Harze, wie Mastix, Olibanum etc. in klare Olea durch Hülff des Spiritus salis destillirt werden.³⁾

For the decoloration of distilled oils, also for the improvement of oils that have darkened with age, such as the oils of cinnamon, cloves and nutmeg, Glauber describes their rectification *per retortam* with *Spiritus salis*.⁴⁾

¹⁾ Johanni Rudolph Glauberi *Furni novi philosophici oder Beschreibung der neu erfundenen Destillirkunst*. Amsterdam 1648 — Leiden 1648 — Prague 1700.

²⁾ An impure muriatic acid obtained by the distillation of common salt with sulphuric acid or alum.

³⁾ Glauberi *Furni novi philosophici*. Editio Prague 1700. Part. 1, pp. 35—36.

⁴⁾ *Ibidem* Part. 1, pp. 39—43.

For the distillation of plant materials with salt and dilute muriatic acid, Glauber gives the following directions:

Die olea aromatum seminum, florum, herbarum, radicum, lignorum etc. werden gemacht, indem die Samen gemahlen, die Blumen, Kräuter und Wurzeln kleingehackt, die Hölzer gerspelt und mit soviel Wasser angefüllt werden, dass dieselben wohl darinnen schwimmen und maceriren können und noch feuchtigkeit genug bleibe, damit dieselben bei der Destillation nicht anbrennen und statt eines lieblichen ein hrenzliches Öl erhalten werde. Trockene Samen, Blumen, Kräuter, Wurzeln und Hölzer müssen zuvur etliche Tage in dem Wasser stehen und sich erhitzen, ehe sie können destillirt werden, und muss auch das Wasser zu den trockenen Species gut gesalzen werden, dadurch dieselben erweichen und ihre olea desto lieber von sich gehen. Zu denen noch grünen Gewächsen ist es nicht nöthig; doch kann es auch nichts schaden, denn das Wasser kann durch Hülte des Salzes desto heisser werden, dadurch die Olea desto lieber steigen, und hilft auch viel dazu dass man Weinstein und Alaun zuthut, welche der Destillation nicht wenig Beförderniss thut. Wenn dann die Species ihre Zeit in dem gesalzenen Wasser gestanden und wohl durchküssen seyn, thut man dieselbe in das Destillirfass etc., so gehet mit dem Wasser, wenn es kochet, des Kraut's, Samen's oder Holzes Öl herüber, und wiewohl auf diese Weise durch Hülff des Salzes vielmehr übergethet, als mit süßem Wasser allein, so bleibt doch noch viel zurück, welches vom Wasser nicht hat ledig gemacht und übergetrieben werden können. Dieserhalben der beste Weg ist, solche olea mit Nutzen zu machen, durch den Spiritum salis zu destillire, wie im ersten Buch gelehrt.¹⁾

Glauber's authority was recognized until the middle of the 18. century, and the methods of distillation recommended by him in his several writings were employed by his contemporaries and their successors. Therefore, Boerhaave, Hoffmann, their contemporaries, and later investigators prepared the volatile oils by using common and other salts, or hydrochloric acid.

It is perhaps due to the observation that metal was present in an oil or a distilled water, especially if an acid had been used in its preparation, that in the course of the 18. century more attention was again bestowed upon the material of which the still was constructed. In consequence glass and glazed earthenware were substituted for metal. As a matter of fact it seems that as early as the 15. century the presence of metals in the distillates obtained from metallic stills did not escape the notice of some of the experimenters. Among others Joh. Krafft²⁾

¹⁾ Glauberi *Furmi novi philosophici*. Editio Prague 1700. Part. 3, p. 30.

²⁾ Crato von Kraftheim, *Concilliorum et epistolarum libri VII*. Francofurti 1589. Vol. 1, fol. 190.

(Crato von Kraftheim, born 1519, died 1585) cautions against the use of copper distilling vessels. The famous Parisian physician Ambroise Paré¹⁾ (born 1510, died 1590) warns against the use of lead helmets and condenser tubes "which oftentimes cause the distilled water to be milky". The Bologna physician and professor, Benedetto Vettori²⁾ of Faenza (Victorius Faventius, born 1481, died 1561) declared about the year 1555, that water, when conducted through lead pipes, dissolves lead and thus becomes poisonous.

However, these observations, like so many others made in the art of distillation, appear either to have been known to but a few, or else were unheeded and again forgotten, for even during the 17. and 18. centuries when oils were distilled with acids, lead and tin heads and condensers were in general use in connection with copper stills or glass and earthenware retorts.

As already mentioned in the preceding chapter, the distillation of the volatile oils and the construction of the distilling apparatus received more attention and underwent a more rapid development with their general introduction into the laboratories of apothecaries. In these the volatile oils used in medicine and the arts were prepared up to the first decades of the 19. century. Only a few oils, such as the oils of lavender, rosemary and rose, which could be produced readily in some countries and which were largely used in the perfume and soap industries, have been obtained since the 16. century in larger quantities by means of primitive portable distilling apparatus.³⁾ The distilling vessels used in the apothecary laboratories and the itinerant stills (*Wanderdestillirgeräte* or *alambics voyageurs*) used in France, Spain, Italy and Bulgaria, consisted of copper stills with a copper or tin head and tin condensing tubes of various shapes.

One of the better distilling apparatus used for the distillation of volatile oils in the 18. century consisted of a tin or copper body suspended in a water bath, and provided with a *Mohrenkopf* (fig. 15, p. 208), a *Rosenhut* (fig. 22, p. 211) and a spiral tube

¹⁾ *Les Œuvres de M. Ambroise Paré, conseiller et premier chirurgien du roy.* Paris 1575. *Editio latina* par Jean Haultin. Parisii 1582. p. 746.

²⁾ Victorii Faventini *Practicæ magnæ de morbis curandis ad thrones, tomi duo.* Veneti 1562. Tom. 1, cap. 21, fol. 144.

³⁾ See pp. 48, 137, 182 and 183.

for condensation. An illustration (fig. 37) and description of this distilling apparatus was published in 1784 by François Demachy¹⁾ (born 1728, died 1803), director of the apothecary laboratories of the civic hospitals of Paris.

The copper kettle *v* serves as a waterbath, which can be turned by the handles *s s* and refilled with a fresh supply of water through the side tube *m*. The tin still *d* rests with the upper ring *n* on the rim *h* of the kettle. The lower neck *q* of the head of the still *b* rests at *n* on the upper rim of the still. Around the lower edge of the head runs the trough *c* in which the distillate that has been condensed in the cone collects and passes with uncondensed vapors through the tube *c - u* into the spiral condenser.

The *Mohrenkopf*, serving as a cooler for the *Rosenhut* *b*, is soldered to the neck *k* of the condensing cone. The water in the cooler warmed during the process of distillation, runs off through the upper tube *e* as fast as cold water is added.

Since the beginning of the 19. century attempts have been made to simplify and to improve the construction of the distilling apparatus, more especially of the cooler, also to prevent the burning of the plants on the bottom of the still caused by the application of direct heat. Such improvements were made



Fig. 37.

¹⁾ J. F. Demachy, *L'art du distillateur des eaux fortes*. Paris 1773. — The German edition bears the following title: *Herrn Demachy's Laborant im Grossen, oder die Kunst, die chemischen Produkte fabrikmässig zu verfertigen. In 3 Theilen. Mit Dr. Struves Anmerkungen und einem Anhang einiger Abhandlungen des Apothekers Wiegleb*. Translated from the French and supplied with additions by Samuel Hahnemann, *der Arzneikunde Doctor und Physicus des Amts Gommern*. 3 Vols. Leipzig 1784. Vol. 1, pp. 192–198 and plate 2, Fig. 1.

especially by Joh. Gottfr. Dingler,¹⁾ apothecary in Augsburg, during the years 1815—1820, by Smithson Tennant²⁾ in 1815 and by Henry Tritton³⁾ in 1818, both of England. The latter attempted to carry on the distillation at a lower temperature by connecting the apparatus with an air pump. The distilling apparatus more commonly in use at that time for the distillation of volatile oils was the one shown in the accompanying cut (fig. 38).

Steam distillation was recommended in 1826 by H. Zeise⁴⁾ and especially for volatile oils by van Dijk in Utrecht,⁵⁾ who thereby materially aided in its introduction. He demonstrated that "the volatile oils which were obtained by steam alone from

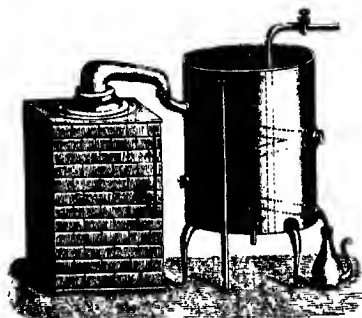


Fig. 38.

the vegetable material, distinguished themselves from those obtained by distillation over open fire, by a lighter color and purer odor. Clove oil distilled with steam is nearly colorless, cinnamon oil light straw yellow and orange peel oil completely colorless."⁶⁾

¹⁾ Trommsdorff's Journ. der Pharm. 11, 1. (1803), 241; also Buchner's Repert. für die Pharm. 3 (1817), 137; and 6 (1819), 142.

²⁾ Philosoph. Transact. of the Royal Soc. of London. 1815. — Repertory of Arts. London. Sept. 1815.

³⁾ Annals of Philosophy. June 1818. — Buchner's Repert. für die Pharm. 6 (1819), 98.

⁴⁾ H. Zeise, *Beiträge zur Nutzenwendung der Wasserdämpfe*. Pamphlet. Altona 1826. — Arch. der Pharm. 16 (1828), 69.

⁵⁾ Buchner's Repert. für die Pharm. 29 (1828), 94.

⁶⁾ *Ibidem* 29 (1828), 110.

The first steam distillation on a larger scale in a pharmaceutical laboratory appears to have been that in the old Apothecary's Hall in London.⁴⁾

In Germany steam distillation for the preparation of volatile oils in apothecary laboratories was also made possible by the introduction of a steam distilling apparatus, constructed about the year 1826 by Johann Beindorff,⁵⁾ mechanic and tin founder

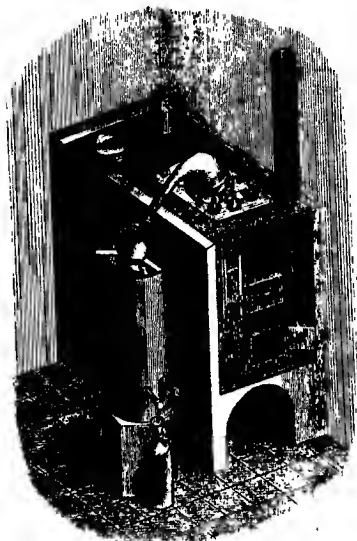


Fig. 39.

in Frankfurt-on-the-Main (fig. 39). With this apparatus, soon perfected in many ways, the distillation of volatile oils with steam under pressure was possible. The condensing arrangement also had the advantage over the spiral tube by being made up of separate parts, and thus allowing it to be readily cleaned even on the inside.

⁴⁾ Buchner's Repert. für die Pharm. 29 (1828), pp. 112 and 113.

⁵⁾ Geiger's Magazin für Pharmazie etc. 11 (1829), 174 and 291. — Buchner's Repert. für die Pharm. 33 (1830), 436.

For the preparation of volatile oils on a small scale, the arrangements based on the original steam distilling apparatus of Beindorff remained, until the industry conducted on a large scale became dominant also in this field and prepared products of a quality and at prices with which the preparation on a small scale could not compete.

Of the arrangements used for a long time for the separation and removal of the oils from the water, the Florentine flask in various forms and sizes has shown its utility and has been in continual use. It probably came into use in the middle ages. A method of separation of oil and water, which in its principles corresponds to those of the Florentine flask, was apparently described for the first time by Porta¹⁾ in the latter half of the 16. century.

"When oils are extracted from plants, those substances which with the water pass over into the receiver must be separated carefully, in order that the oil, which contains an excess of phlegm, may not be weakened. Hence the oil must be rectified in order that it may retain its full strength. This is accomplished by distillation and separation. For this purpose the first distillates are mixed, poured into a retort placed into a water bath (*in balneo Mariæ*) and slowly distilled over. The pure oil will float on the surface of the aqueous distillate. The separation of the oil from the water demands painstaking labor. For this purpose, however, ingenious vessels have been devised which admit of the ready separation of water and phlegm from the oil. The glass vessel serving this purpose is open at the top and widens out funnel-like toward the bottom. The water, phlegm and oil are transferred slowly, drop by drop, into this flask, whereby the oil rises to the surface. A lateral tubular opening is closed with the finger. By effecting a partial opening the lower layer of water is allowed to flow out, whereas the oil collects above the opening closed by the finger. Thus the oil is separated from the water that has been allowed to flow out. Finally the oil is transferred to another container.

"Still another separating vessel has been devised for this same purpose. The bulging flask contracts to a narrow neck, to the middle of which is attached a bill-like tube. The oil mixed with water is poured into this flask, the water remains below, the oil rises to the surface and into the neck. Water is then added drop by drop so that the pure oil flows drop by drop out of

¹⁾ Joh. Baptistæ Portæ, Neapolitani *Magiæ naturalis libri viginti, in quibus scientiarum naturalium divitiæ et deliciae demonstrantur. Iam de novo, ab omnibus mendis repurgati, in lucem prodierunt.* Romæ 1565. Antwerp. 1567. Editio Hanoviz 1619. *Liber decimus: Destillat, destillata ad fastigia virium sustollit.* p. 367—412.

the bill. In the case of other oils which sink to the bottom, the water is allowed to flow out above. Any water remaining at the surface is removed by cotton (a lamp wick) whereby the purest oil remains behind."¹)

The Florentine flask, like many other improvements pertaining to the art of distillation which were not generally known, was soon forgotten. As a result it was rediscovered several times from the beginning of the 17. century to the year 1823. Thus the flask was again described and introduced by Homberg²) at the end of the 17. century, about one hundred years after Porta's description — only, however, again to be forgotten for a considerable period of time. A century later, in the year 1803, the Florentine flask was again recommended for the distillation of volatile oils by the Augsburg apothecary Johann Gottfried Dingler³) and later in 1823 once more introduced as something new by the apothecary Samuel Pectz⁴) in Pesth.

The Florentine flask of older construction, as described by Porta, has been in use for a long time. The oil was siphoned off by means of a porous siphon consisting of a lamp wick into small bottles (fig. 40). Later the Florentine flask shown in fig. 41 was also used. The flask used at the present time in the large factories is not only larger, but contains in the upper part on a level with the oily layer a glass stopcock through which the oil can be drawn off from time to time (fig. 43), or an overflow tube through which the oil when it reaches a certain level runs into a receiver (fig. 42).

In the course of time a number of differently constructed receivers for the separation of the volatile oils have been proposed,

¹) " . . . Quomodo oleum ex aquis separemus aliud separatorium vas ad idem ingenuosissime excogitatum est, tenuet venter vasis, collum angustum est, cujus medio rostellum affixum est. Transfundatur in vas oleum aqua remistum, occupat aqua fundum, oleum supra collum: guttatim aquam addes, donec oleum ascendat ad rostellum, ex permento, inclinato vase, descendet purissimum oleum et purgatum, ubi aliquid evacuaſti, sensim aquam addendo, ascendit oleum ad canaliculam coq.; iterum inclinato, reliquum transfundas. Si vero oleum subsidet, aqua super adlatur, ut multoties eveniet, in latam fideliā vel quodcunq.; vas impositum, gossipino licineo adaptato, aqua foras transmeabit, oleum purissimum quod superest, in fundo residet".

²) Philippe and Ludwig, *Geschichte der Apotheker*. 1858. p. 513.

³) Trommsdorff's *Journ. der Pharm.* 11, II. (1803) 242.

⁴) Buchner's *Repert. für die Pharm.* 14, III. (1823), 481.

without however, causing the Florentine flask to be discarded. The first of these was proposed by Amblard of Paris¹⁾ in 1825. It consisted of a conical glass tube, open at both ends and drawn out to a taper. This tube was suspended by means of a cork ring at its upper end in a high glass mixing cylinder. This cylinder was provided at the top with an overflow tube. The oil collects in the glass tube and can be removed from this after closing the small lower opening, by pouring out as often as desired.

The more salable volatile oils which were used in larger quantities in the perfume industry that had developed in France in the course of the 18. century were still prepared during the first quarter of the 19. century in the traditional primitive distilling



Fig. 40.



Fig. 41.

vessels, and were improved by rectification. In Germany the apparatus shown in figs. 38 and 39 were principally used. While the oils of lavender, rosemary, orange flower, and other fragrant oils (*essences*) were manufactured in France, and rose-oil in Turkey, Germany and Hungary supplied the market with the oils of caraway, fennel, anise, coriander, calamus, peppermint, spearmint, valerian, chamomile, and others used in medicine and in the fine arts. In southern France, especially on the sunny slopes of the Alps near the Mediterranean coast, the industry of the aromatic oils developed considerable proportions in the early part of the past century. The oils principally used for medicinal purposes, however, were still prepared in apothecary labor-

¹⁾ Bulletin des travaux de la Société de Pharm. Paris, May 1825, p. 247.

atories. In the course of time certain apothecaries and druggists, having made a beginning on a small scale, erected much larger establishments for the preparation of volatile oils. This was done especially in regions suited to the cultivation of medicinal plants, for instance, in Thuringia on the Saale and the Elbe, in Saxony, Bohemia, Franconia, and also in Hungary. Only a few of these, however, remained in existence for any appreciable length of time. As in other branches of chemical industry, these originally small distilling operations were replaced everywhere by a larger, more rational and efficient industry. Since the middle of the past century this new industry has worked hand in hand with science and technology. It has not only enlarged, but also improved the conventional methods and apparatus

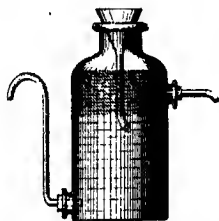


Fig. 42.

Receiver for oils lighter than water.



Fig. 43.

Receiver for oils heavier than water.

for distillation. Whereas on the one hand it utilized the results of science, on the other it not only stimulated science, but gave direct assistance.

Beginning about the middle of the past century the earlier, simple apparatus took on a different shape in the factories of this larger industry of the volatile oils. The original small distilling apparatus were replaced by larger and more rationally constructed ones which not only effected a better exhaustion of the vegetable matter and thus increased the yield, but also produced oils of a better and purer quality.

The apparatus commonly used in the factories about the middle of the present century, were the stills arranged for the so-called water-distillation, and others for the so-called dry steam-distillation.

The first type of still (fig. 44) is a simply constructed apparatus for the distillation of plant material in water, as well as for the rectification of crude oils by steam. The still is heated by means of steam admitted under pressure through the holes of a ring *d* at the bottom, or by allowing the steam to escape directly into the lower double walled jacket *B*. The aqueous distillate constantly flows back into the still through the tube *F*.



Fig. 44

In the distillation with dry steam (fig. 45), the still is filled with the plant material without the addition of water and distilled with steam passing through the material from the bottom upwards. These or similarly constructed steam distilling apparatus are employed even at the present time for the distillation of some of the oils, only, in place of the spiral, a tube condenser is used.

With the introduction of these apparatus during the middle of the past century the volatile oil industry had taken its position as a branch of the rapidly developing chemical industry at large with southern

France and central Germany as the principal centers of production.

Owing to the remarkable development of the entire perfume industry during the second half of the past century, the consumption and commerce of the volatile oils assumed entirely unanticipated proportions and importance. Scientific and technical attainment, commercial interests and business competition brought about numerous changes in rapid succession. More rational methods of distillation were devised, large apparatus

for the distillation of enormous quantities were constructed. Some of the largest have a capacity of from 30 000 to 60 000 liters.

The evolution of the modern distilling apparatus as applied to the distillation of volatile oils, like that of the theory and art of distillation in general, is replete with historical interest.

On the following pages will be found a number of illustrations of some of the modern stills used in the largest German factory. Looking backward it might seem as though there were no connection between the modern giant stills and their prototypes. Yet every one of them is but a link in the long chain of develop-

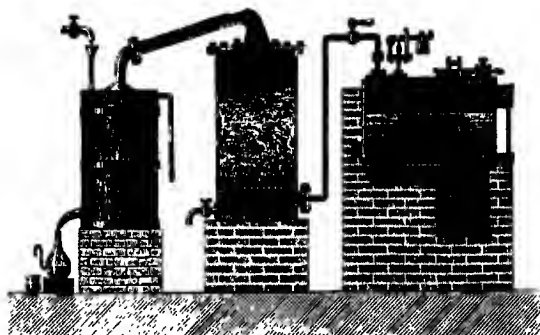


Fig. 45.

ment of the art of distillation. That the process of evolution has been exceedingly rapid during the past ten years does not affect the truth of this statement. Almost every one of these pieces of apparatus has been newly created out of the ruins of its immediate predecessor.

In modern chemical industry Germany unquestionably ranks first. Of the various branches of this industry that of the manufacture of volatile oils and synthetic aromatics has acquired an importance previously unexpected and with it a correspondingly influential position.



Fig. 46.

Modern distilling and rectifying apparatus.

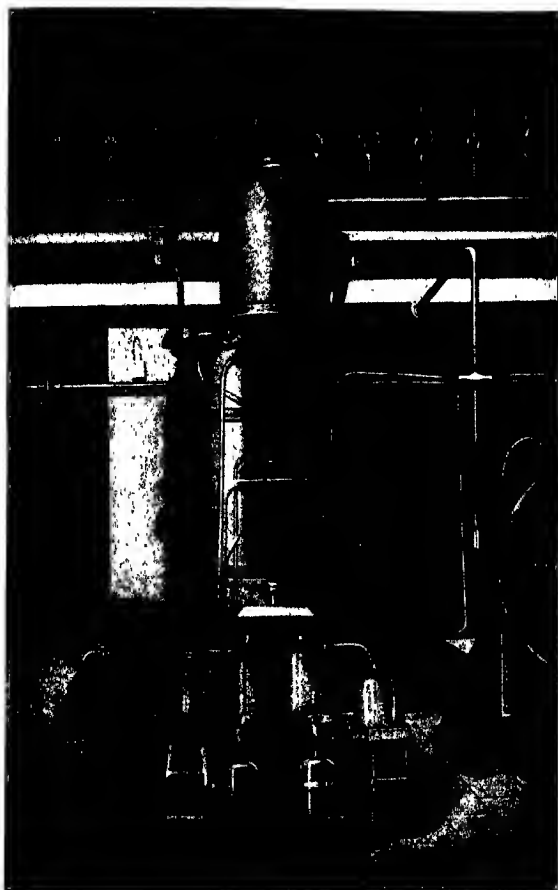


Fig. 47.

Distilling and rectifying apparatus.



Fig. 48.

Distilling apparatus for water distillation.

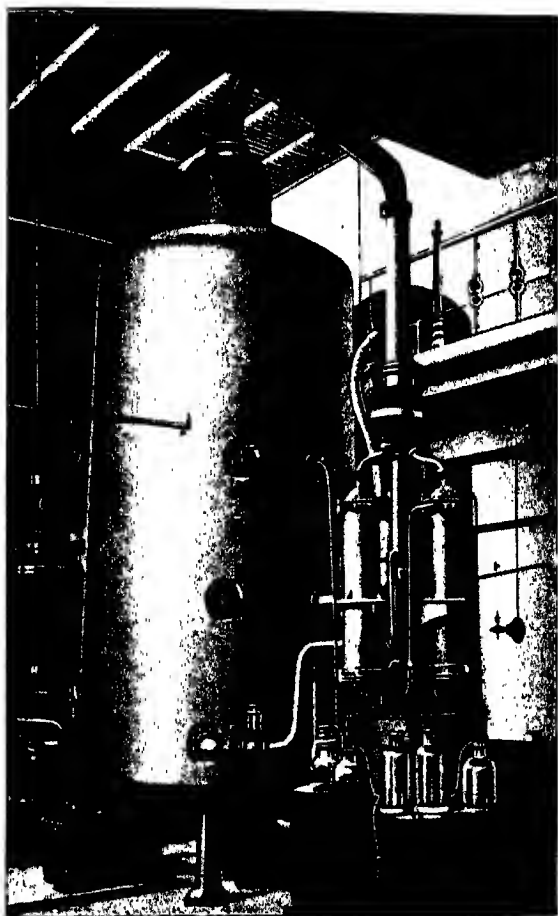


Fig. 49.

Distilling apparatus of 30000 liter capacity.

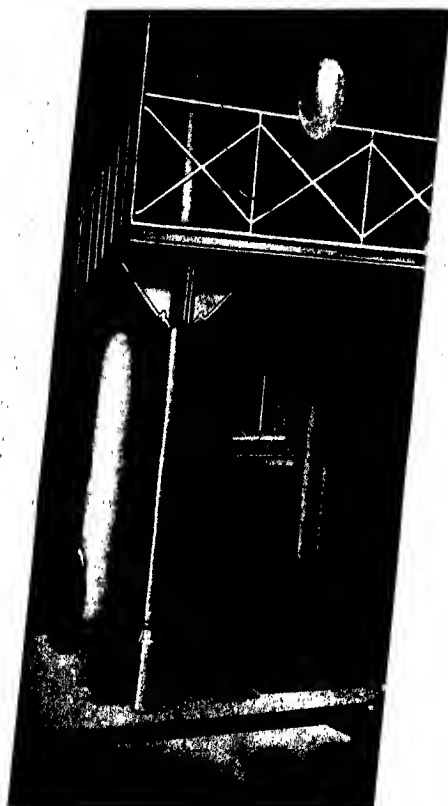


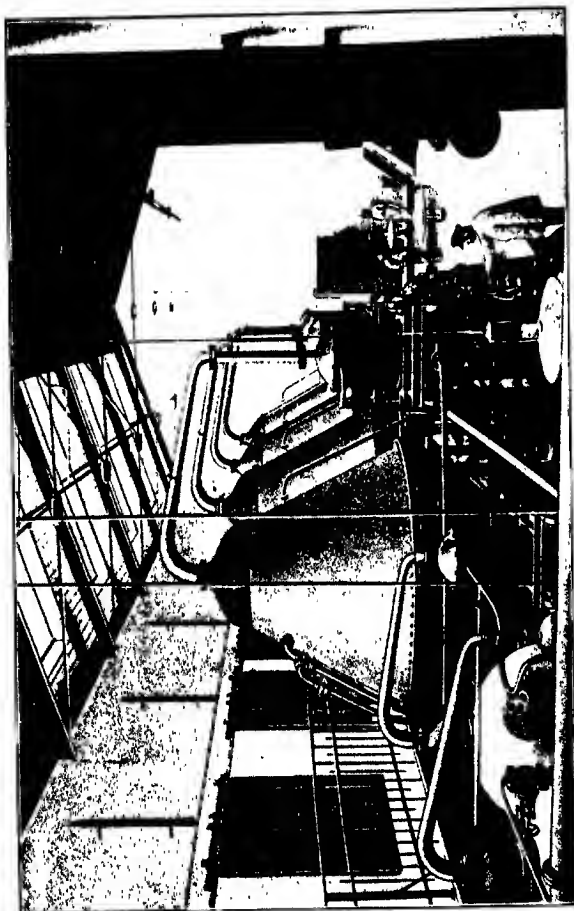
Fig. 30.

Distilling apparatus for spices.



Fig. 51.

Giant distilling apparatus of 60 000 liter capacity.



Distillation of rock oil



Fig. 53. Modern distilling apparatus.



THE PRODUCTION OF FLOWER PERFUMES

BY EXTRACTION, ENFLEURAGE, AND MACERATION.



The most common method for the production of volatile oils is that by steam distillation. This method not only produces the best yields and the purest oils, but also enables the operator to attain the end sought most cheaply and with the simplest apparatus. Furthermore, large quantities of oil can thus be produced without much human labor. In particular instances, however, distillation does not produce the desired result. This is particularly true when the high temperature of the steam destroys the unstable perfume substances, or when the amount of oil is relatively small, moreover if it is readily soluble in water. In such instances distillation may, under favorable circumstances, yield a fragrant water, which, even by colobation, may not separate a volatile oil.

As a matter of fact, some of the most fragrant parts of plants, namely the flowers, are not suited to steam distillation. In order to prepare the odoriferous substances which impart to them their fragrant odor, other methods are employed. In such cases the volatile oils may be extracted either with volatile solvents or with fat, or they are allowed to be absorbed by fat.

Hence a distinction is made between:

- A. Extraction with volatile solvents.
- B. Extraction with nonvolatile solvents, *i. e.* fats.
 - 1. Without the aid of heat: enfleurage.
 - 2. With the aid of heat: maceration.

Which of these methods is best adapted to the extraction of the perfume of a particular flower has been determined in southern France by long years of experience.

Extraction with volatile solvents is applied to roses, Parma and Victoria violets, orange blossoms, jasmine, tuberose, jonquil,

cassie, and mignonette, occasionally to carnations, lily of the valley, heliotrope, elder flowers, stock, narcissus, and mimosas. In like manner a concrete oil is prepared from the so called *Mousse de chêne*, the lichen *Evernia prunastri*.

Enfleurage yields the best results with jasmine, tuberose, jonquil, lily of the valley, and mignonette.

Finally, the process of maceration is applied to rose, orange flower, violet, cassie, and lily of the valley.

As becomes apparent, some flowers e. g. rose, cassie and violet, can be treated equally well either with volatile solvents or with warm fats. It has been known for a long time that jasmin and tuberose when thus treated give an unsatisfactory yield, whereas the enfleurage process gives good returns.

Passy¹⁾ who first called attention to this fact, gives the following explanation for this difference in behavior of the several flowers.

"Flowers can be divided into two classes of which the one, to which rose and orange flower belong, contain their perfume ready made. The other, to which belong jasmin and tuberose, contain either no ready made volatile oil or but very little thereof. These, however, continually produce perfume as a part of the life process of the cells. If the flower be killed by petroleum, ether, or hot fat, the life process and with it the formation of volatile oil naturally ceases. If, however, the cut flower be placed over fat, it continues to live for a long time and to emanate odors which in the enfleurage process are absorbed by the fat."

When Hesse²⁾ tested experimentally this hypothesis he arrived at the surprising result that in the case of jasmin the enfleurage process yields ten times the amount of oil yielded by the extraction with volatile solvents. In the case of tuberose the proportion is even greater. Hence the conclusion is justified that in the case of the jasmin and tuberose the production of odoriferous substances continues during the process of enfleurage, being absorbed as it is formed. This also proves the superiority of the enfleurage process over that of the extraction method for certain flowers. For other flowers this does not hold true.

¹⁾ Compt. rend. 124 (1897), 783; Bull. Soc. chim. III. 17 (1897), 519.

²⁾ Berl. Berichte 34 (1901), 293, 2928; 36 (1903), 1465.

Thus, according to Hesse and Zeitschel,¹⁾ 1000 ko. of orange blossoms yield only 100 grams of volatile oil when submitted to the enfleurage process, whereas maceration yields 400 grams and distillation with steam 1200 grams of oil, of which, however, about 400 grams are dissolved in the aqueous distillate.

A. EXTRACTION WITH VOLATILE SOLVENTS.

The first to suggest the use of volatile solvents for the extraction of flowers was Robiquet. In a paper²⁾ contributed in 1835 he points out that some plants, such as jonquil, jasmine, heliotrope, and tuberose, in spite of their agreeable fragrance, yield no volatile oil when treated in the ordinary manner. He ascertained that the odoriferous principle of jonquil, could be obtained by extraction with ether and subsequent evaporation of this low-boiling solvent. A year later L. A. Buchner,³⁾ stimulated by the report of Robiquet, ascertained that ether could also be used for the extraction of other flowers with a readily evanescent aroma, such as those of *Philadelphus coronarius*, *Tilia europæa*, and *Reseda odorata*. In 1838 Favrot⁴⁾ proceeded in like manner with the extraction of the perfume of the *flores acaciæ* (presumably the flowers of *Robina pseudacacia?*), also of the flowers of *Syringa vulgaris*.

A more detailed study of the extraction of flowers with volatile solvents was made by Millon⁵⁾ in Algiers. In addition to ether he recommended chloroform, carbon disulphide, wood alcohol and the low boiling fractions of benzin.

¹⁾ Journ. f. prakt. Chem. II. 64 (1901), 245.

²⁾ *Recherches sur l'arome de la jonquille*. Journ. de Pharm. 21 (1835), 335; Buchner's Repert. f. d. Pharm. 54 (1835), 249; Pharm. Zentralbl. 1885, 553.

³⁾ *Versuche zur Extraktion der Blüten mit Äther*. Buchner's Repert. f. d. Pharm. 56 (1836), 382.

⁴⁾ Journ. de Chim. méd. 1838, 221; Pharm. Zentralbl. 1888, 442.

⁵⁾ *Mémoire sur la nature des Parfums et sur quelques fleurs cultivables en Algérie*. Journ. de Pharm. et Chim. III. 30 (1856), 407; Compt. rend. 48 (1856), 197.

Millon placed the flowers into a percolator (*appareil à déplacement*) covered them with ether and renewed the menstruum after 10 to 20 minutes. The extract, obtained after evaporation of the ether, he kept in open containers because he thought that the air acted favorably on the odoriferous principle. This, however, was a deception. Unless the solvent is carefully removed with the aid of a vacuum, mere traces of it can be detected if the extract is kept in closed containers. Millon was not ignorant of the fact that the greater part of the extract consists of vegetable wax which is well nigh insoluble in alcohol. Hence he determined the amount of odoriferous substances by ascertaining the difference in weight of the extract before and after treatment with alcohol.

Millon also pointed out that the time of day in which the flowers are collected is an important factor. Thus carnations should be gathered after 2 to 3 hours of intensive sunshine, roses in the morning after they are fully blown, jasmine before sunrise. To a sensitive nose cassie flowers have a different odor according to the time of their collection, morning, noon or evening. Millon recommends that the following flowers be extracted: orange blossom, tuberose, heliotrope, stock and narcissus.

The substitution of petroleum ether for ether, a practice now in common use, was suggested by H. Hirzel¹⁾ of Leipzig. His apparatus constructed for this purpose, were patented as early as 1864 in France, England, Austria, and several of the German states. The problem of utilizing on a technical scale the extraction with ether, carbon disulphide, chloroform, and petroleum ether, was developed about the same time by A. Piver.²⁾ The use of methyl chloride as a solvent was recommended by Camille Vincent.³⁾

In the early seventies, Louis Roure⁴⁾ devised a method for the preparation of the so called *essences concrètes*, concentrated alcoholic perfumes, obtained by extraction. These were exhibited at the Vienna Exposition in 1873. A very complicated apparatus was patented by Laurent Naudin⁵⁾ in 1875. This permitted of the vacuum distillation of the solvent charged with the perfume.

However, it is only since the last 25 to 30 years that the method of floral extraction with volatile solvents has found industrial application. It was at that time that Massignon in Cannes erected a battery of extraction apparatus similar to the diffusion apparatus employed in sugar factories. The solvent saturated

¹⁾ Hirzel's *Toiletten-Chemie*. III. ed. Leipzig 1874, p. 77.

²⁾ *Ibidem* p. 79.

³⁾ Piesse, *Chimie des parfums*. 1903, p. 69.

⁴⁾ *Berichte von Roure-Bertrand Fils* October 1900, 27.

⁵⁾ *Bull. Soc. chim.* II. 38 (1882), 586 to 600.

with the perfume was evaporated in a vacuum still. As menstruum Massignon first used ether, carbon disulphide, methyl chloride, and benzene. Finally he arrived at the conclusion that a petroleum ether of the specific gravity 0,650 was best suited. Later Massignon sold his factory and his patents to Léon Chiris. Gradually other factories were equipped with extraction batteries. At the present time there are about 15 larger establishments of this kind in Grasse. In Joffa, Garnier erected a factory for the extraction of cassie flowers, and in Kara-Sarlî near Karlova in Bulgaria, another for the treatment of roses according to the extraction method. Recently a factory has been established for the extraction of cassie flowers and of other flowers cultivated in the island for this purpose.

Practically the process of extraction with volatile solvents resolves itself into four steps:

1. Selection and purification of the solvent.
2. The systematic extraction of the flowers.
3. Evaporation of the solvent and production of the vegetable wax saturated with perfume (*cire parfumée*).
4. Recovery of the solvent.

1. SELECTION AND PURIFICATION OF THE SOLVENT. The solvent most commonly used is petroleum ether of a specific gravity 0,650 (15°). It is purified by consecutive treatment with sulphuric acid and caustic soda, washing with water and rectification with the aid of a column in a still over solid paraffin for the purpose of removing the lighter as well as the heavier fractions. Less frequently benzene is used since it has the disadvantage of yielding a highly colored extract. Carbon disulphide is not serviceable since the extract always retains some of the disagreeable odor of the solvent. Neither has carbon tetrachloride maintained itself. The high price of ether stands in the way of its general use.

2. THE SYSTEMATIC EXTRACTION OF THE FLOWERS. The extractors of the mounted extraction batteries are cylindrical vessels, varying in size, but usually of about 500 liter capacity. They contain 3 or 4 low cylinders made of wire gauze or of perforated tin, one placed over the other. The extractors are

airtight and sealed with a removable cover. The batteries are mounted in one of several ways: either the extractors are all on a level in a circle or a row (fig. 56, p. 254), or in two tiers one over the other (fig. 54, p. 252). With the aid of a pump, the solvent can be passed from one extractor to another.

As a rule, 3 to 4 extractions are made within 24 hours. Hence the menstruum remains in contact with the flowers from 6 to 8 hours. Then the flowers are replaced by fresh ones. However, during the height of the harvest the flowers in the extractors are replaced every 8, or even every 4 to 5 hours. This hastening of the process, however, results in an imperfect extraction.

As a rule, each batch of flowers is extracted three times, more rarely twice or four times. For the third (or last) extraction fresh petroleum ether is used, for the second such which has served for a former third extraction, and for the first extraction (*i. e.* for fresh flowers) the menstruum which has once served for a second and once for a third extraction. The percolate of each extraction is collected in a separate receiver.

Whether the same batch of flowers is to be extracted two, three, or four times, or even oftener depends upon the nature of the flowers to be extracted and on the views of the manufacturer. There exists also a difference of opinion as to how often the same petroleum ether can be used before it is to be recovered by distillation.

In order to increase the yield, the extractors have been so constructed in several instances as to enable their being warmed. This has resulted in a larger yield of wax but not of odoriferous constituents.

3. EVAPORATION OF THE SOLVENT. The manufacturer operates one or several stills under ordinary pressure or in vacuum. As a rule the bulk of the solvent is recovered in a large still under atmospheric pressure until the temperature has reached a point that would prove detrimental to the fineness of the perfume. The distillation is then continued in a vacuum still and finally concluded in a glass flask.

The last traces of solvent are removed by passing small amounts of alcohol into the molten wax thus causing a violent ebullition.

The floral extracts thus obtained are designated "concret oils" (*essences concrètes*). The alcoholic extracts prepared from these, according to the method described below, are known as floral extracts (Ger. *Blüten extrakte*; Fr. *extraits aux fleurs*; the pure oils remaining after the removal of the alcohol *quin essences*.¹⁾

4. RECOVERY OF THE SOLVENT. On account of the expense of the solvent, suitable devices are provided to prevent loss. Hence long and well cooled spirals are used to condense the vapors from the stills, the extractors and the reservoirs. The ejectors of the vacuum pump must also be provided with a efficient condenser. If the process is conducted without a vacuum, the petroleum ether losses are less, but evaporation under atmospheric pressure, as already pointed out, results in an impairment of the fragrance of some of the floral constituents.

The solvent adhering to the flowers after their extraction is recovered by passing steam through the extractors which, for this purpose, are connected with the condensers; or by transferring the flowers to a still from which the solvent is recovered by steam.

Yield. The yield varies greatly according to the solvent and temperature employed, also according to the duration of the extraction.

At ordinary temperature, petroleum ether yields for every kilo of flowers the following amounts of concrete oils.

| | | |
|----------------------------|------------|--------|
| Victoria violets | 1,5 to 1,8 | g |
| Roses | 1,7 " | 2,5 " |
| Orange flowers | 2,0 " | 4,0 " |
| Jasmine | 1,6 " | 2,25 " |
| Cassie | 3,5 " | 5,0 " |
| Mignonette | 1,3 " | 1,5 " |

Removal of the plant wax from the concrete oils. For this purpose the *essences concrètes*, i. e. the extracts obtained by percolation and subsequent evaporation of the solvent, are shaken for several days with strong alcohol, preferably in shaking machines (*batteuses*). The alcoholic solution, after being

¹⁾ Jeancard et Satie, *Abrégé de la Chimie des Parfums*. Paris 1904, p. 12.

separated from the insoluble wax, is cooled for some time to 0° . This causes the separation of the dissolved wax, which is removed by filtration. To the alcoholic filtrate a solution of common salt is added, and the perfume, which has risen to the surface, is separated. If necessary, the last traces of alcohol are removed with the aid of a vacuum.

In as much as the plant wax when shaken with alcohol agglutinates to a magma from which the perfume is extracted

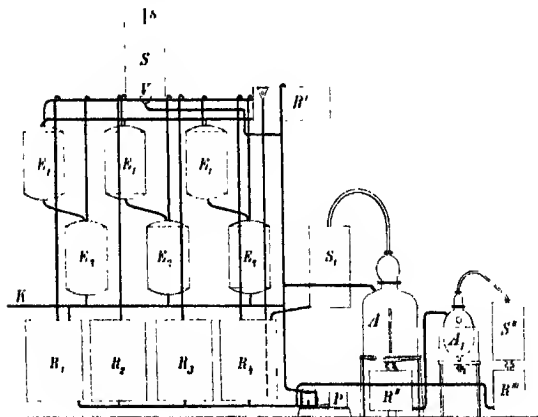


FIG. 54.

Elevation plan of an extraction battery.

with difficulty, Massignon¹⁾ has suggested to mix it with a very hard and odorless mineral wax, thus yielding a mass that can be broken up in a mortar. The particles then remain suspended in the alcohol and are more readily extracted by it.

DESCRIPTION AND OPERATION OF THE EXTRACTION BATTERY REPRESENTED BY FIG. 54, P. 252.

In the above plan the extractors are marked E_1 and E_2 . They have a capacity of about 500 l. and are divided into compartments by means of 3 to 4 false bottoms of perforated tin or by means of wire baskets. The air tight

¹⁾ P. Jeancard, Volatile solvents applied to flowers. *Americ. Perfumer* 1 (1907), 10.

covers are provided with two pipes: one of these is used for introducing the solvent, the other for ventilation. The ends of the pipes are flexible and can be screwed to the cover. The bottom of the extractor is slightly conical thus admitting of a complete evacuation of the extract through the pipe fastened to its center.

S is a condenser in which the vapors that might otherwise escape are liquified. The condensate collects at *V* and flows into the reservoir *R*₁.

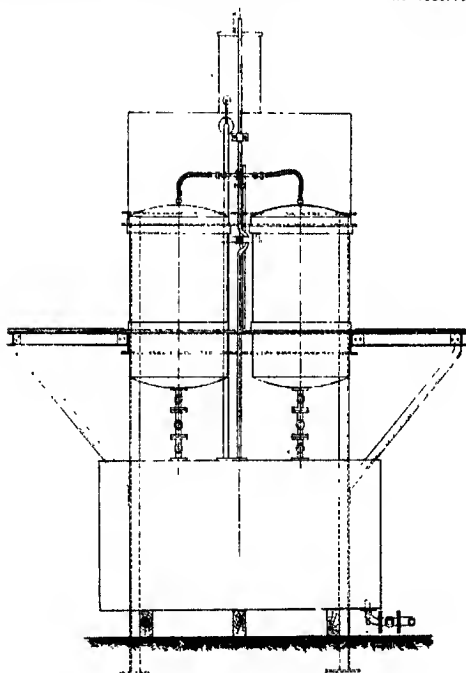


Fig. 55.

Side view of an extraction battery by Deroys Fils Ainé, Paris.

Vapors that have not been condensed as well as air escape through *s*, *S*₁ and *S*'' are the respective condensers for the stills *A* and *A*₁.

A is a larger still for distillation under atmospheric pressure. It is provided with a glass tube indicating the height of the liquid and with a thermometer. The distillate passes through the condenser *S*₁ into the reservoir *R*₁. The residue is allowed to flow into the container *R*''.

*A*₁ is a vacuum still which can be heated by means of a water bath. It is filled by suction from *R*'''. The recovered solvent collects in *R*''' from which it is pumped to the larger reservoirs.

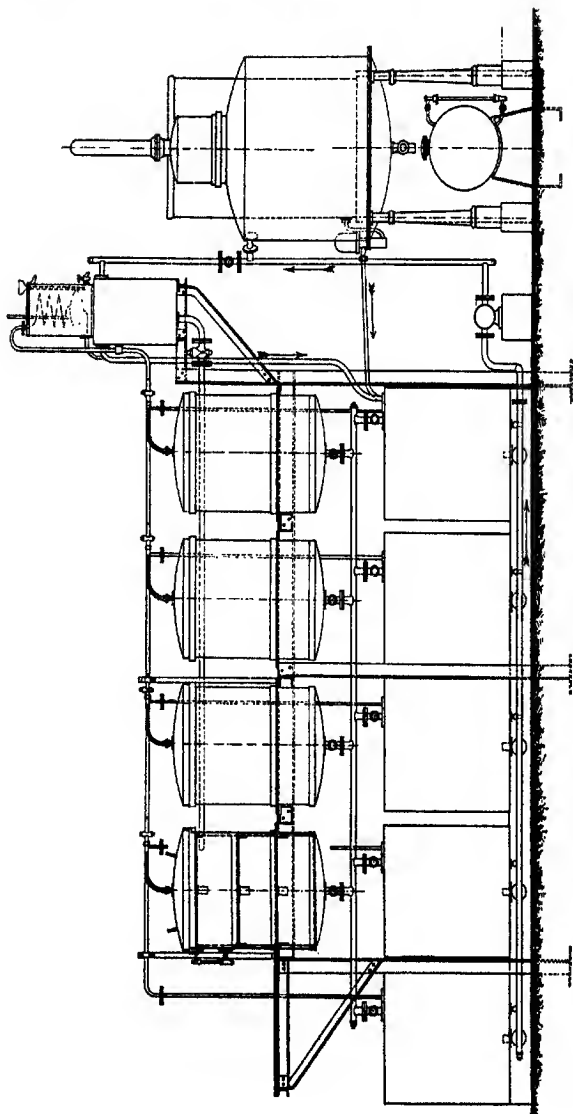


Fig. 56. Sectional front view of an extraction battery by Deroy Fils Ainé, Paris.

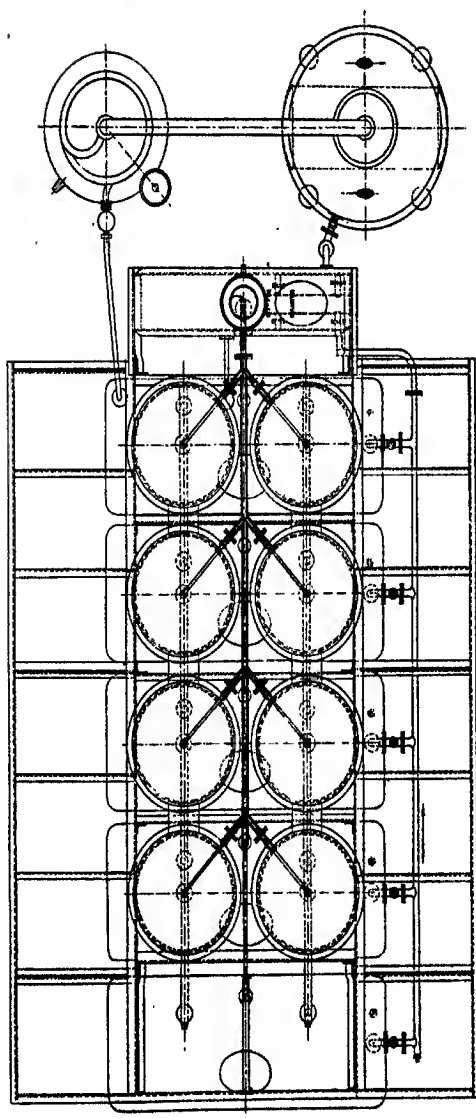


Fig. 57. Ground plan of an extraction battery by Deroy Fils Ainé, Paris.

R_1 , R_2 , R_3 , R_4 are reservoirs of about 2000 l. capacity provided with glass tubes showing the height of the contents and with ventilation tubes. With the aid of a pump the contents can be transferred to the extractors.

The extractors are filled from R' which is provided with an overflow into which the solvent is pumped from the other reservoirs with the aid of pump P .

The pipes are indicated by heavy lines. All parts of the battery and the intersections of the pipes are provided with one-way or several-way stopcocks.

The purified solvent passes through pipe K into the reservoirs R_2 , R_3 , R_4 , which are filled to about $1/2$ of their capacity. The flowers are then

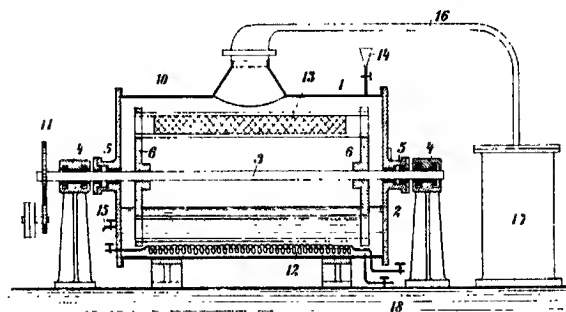


Fig. 58.

Longitudinal section of Garnier's extraction apparatus.

placed on the false bottoms in the extractors E , the covers are placed in position, the influx and ventilation pipes are adjusted, and the solvent is allowed to flow from R' into the extractors E_1 until the flowers are completely covered. The three extractors E_2 are next filled and the flowers are covered with the percolate of the upper tier of extractors, the flowers of which are covered with fresh solvent. In this manner the flowers are commonly extracted three times in succession. These three extractions are made within 24 hours, but in the rush of the floral harvest are sometimes made in 8 hours, or even in 4 to 5 hours.

The percolate of each extraction is stored away separately, reservoir R_1 , containing the first percolate. After the petroleum ether has been sufficiently saturated with perfume it is recovered first by distillation in the still A , then under diminished pressure in A_1 , and finally in a glass flask.

The exhausted flowers are allowed to drain well. The menstruum still adhering to them is recovered by steam distillation in the large still.

DESCRIPTION OF GARNIER'S APPARATUS FOR THE EXTRACTION OF FLOWERS.

Figures 58 to 60 illustrate an apparatus constructed by Garnier¹⁾ for the extraction of flowers. It consists of a stationary outer cylinder, (figs. 58 and 59) which at 2 is provided with a manhole that can be hermetically sealed. Within there is a drum that revolves about the shaft 3 (fig. 58), that passes through the outer cylinder at 5 and rests upon supports at 4.

The end pieces of the inner drum has twelve circular openings 7 near the circumference (fig. 60). Each of these openings is connected with the corresponding one at the opposite end of the drum by means of a circle of rods which effect a hollow cylinder. Into these hollow cylinders, of

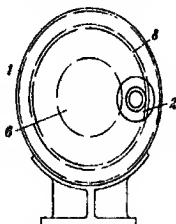


Fig. 59.

Transverse section of Garnier's
extraction apparatus.

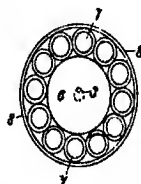


Fig. 60.

Transverse section of the inner drum
of Garnier's extraction apparatus.

which each drum has twelve, cylindrical baskets 13 of perforated tin can be placed (fig. 58).

The power which is transmitted by cogwheels at 11 put the drum into rotary motion. By means of a spiral tube 12 the liquid in the outer cylinder can be gently heated. The tube 16 connects the apparatus with a condenser 17, hence it can be used as a still.

Operation begins by introducing the cylindrical baskets 13 filled with flowers, through the man hole 2 (fig. 59) into the drum. Enough solvent, petroleum ether, is then introduced through the funnel 14 (fig. 58) so that the lowest flower basket is completely covered thereby. The drum being revolved causes the baskets one after the other to be dipped into the solvent. The flowers having been exhausted, the extract is withdrawn by means of a stopcock 18. Steam is then passed through the apparatus in order to recover any solvent adhering to the flowers.

¹⁾ Comp. p. 249.

B. EXTRACTION WITH NON-VOLATILE SOLVENTS.

1. WITHOUT THE AID OF HEAT: ABSORPTION OR ENFLEURAGE À FROID.

The absorption method, known as *enfleurage*, applied to those flowers which continue to produce volatile oil even after they have been removed from the stem (p. 246), depends on the capacity of fats or fatty oils to absorb the oil volatilized by the flowers and to hold it. This process is carried out in a relatively primitive manner. As already stated on p. 246, it is applied to jasmine, tuberose, jonquil, lily of the valley, and mignonette.

For the purpose of *enfleurage*, so called *châssis* are used. These are wooden frames 5 cm high and 50 to 80 cm square. A glass plate is supported in the middle of the frame. On either side of this glass plate a layer of fat about 3 mm in thickness is spread in such a manner as to leave a margin 4 cm wide (fig. 61, p. 259). The flowers, deprived of their calices, are then spread over this layer of fat (*enlleurer*) (fig. 62, p. 261). In order to enlarge the surface of the fat exposed to the flowers criss cross furrows are drawn through it with the aid of a spatula. Thirty-five to forty of the *châssis* thus prepared are piled one on top of the other to the height of a man. As a result the flowers are enclosed in small chambers, as it were, between two layers of fat, which absorbs the aroma. The length of exposure depends on the kind of flower: *jasmin* 24 hours, *jonquil* 48 hours, *tuberose* 72 hours. Moreover, the last mentioned are placed on fat in the unopened stage and are allowed to expand while resting on the fat. If they are placed on the *châssis* fully developed they are spoiled by the next day (*pourri*). After the flowers have remained on the fat for the requisite length of time, they are removed by a rap on the frame or with the aid of the fingers (*delleurer*) (fig. 62, p. 261). The *châssis* are then charged anew but this time on the other side so that the flowers now rest on the layer of fat which in the previous exposure was the upper one, thus producing a more even

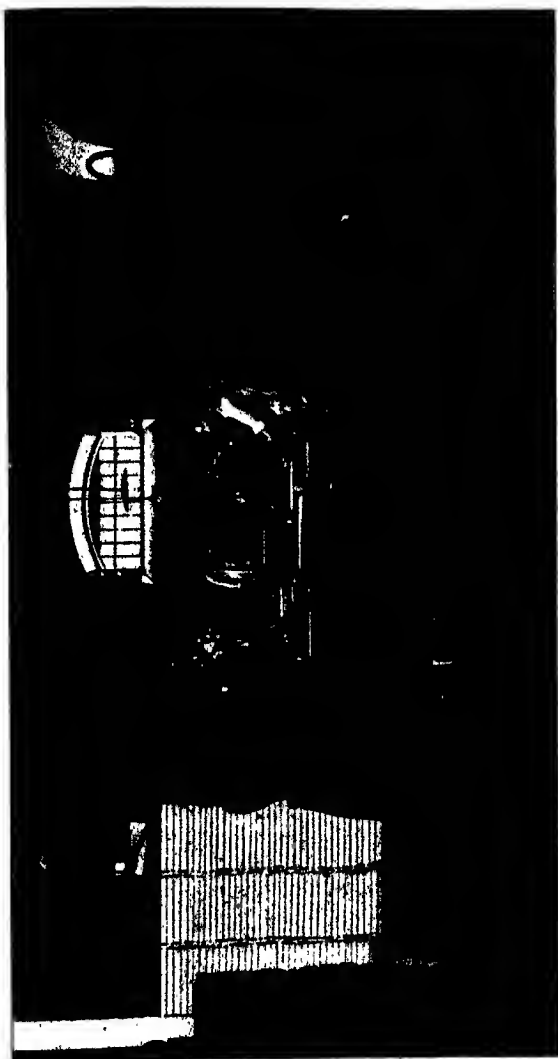


Fig. 61.
Spreading the layer of fat on châssis (*Pilage des châssis*). Parfumeries de Seillans, Dép. du Var, Southern France.

charging of the fat with perfume. This process can be repeated as often as desired until the fat has absorbed a sufficient amount of oil. The price of the pomade (*Pommade française*) depends on the number of exposures. As a rule the fat is exposed 30 times.

The production of a good pomade depends first of all on the character of the fat which must be purified with great care. In as much as lard is too soft and beef fat too hard, a mixture of both is commonly used for enfleurage, e. g. 40 parts of beef fat and 60 parts of lard. During the hottest months a mixture of equal parts of both is used. The fat of recently killed animals is cut into pieces and all impure or malodorous parts are removed. The good parts are then further reduced and rendered in a special apparatus, the tissues and other impurities being removed. In order to remove traces of blood, the mass thus resulting is ground between mill stones with the aid of water until the latter remains clear. The fat is next melted at the lowest possible temperature in a jacketed steam pan and alum is added. The alum facilitates the coagulation of impurities which rise to the surface and can be removed with the aid of a skimming spoon. The molten mass is allowed to stand for several days, the separated water is removed and the fat strained through linen. The fat thus obtained is preserved in one of several ways. The fat is digested for an hour with gum benzoës (about 1 to 3 g for each kilo of fat)¹⁾ and either orange flowers (according to Pillet 250 g for each kilo of fat)²⁾ or, less frequently, with rose water (about 40 g for each kilo of fat). This mixture is then allowed to stand for several hours and the fat, freed from water drawn, into the containers. This is done in May at the time of the orange flower harvest. The fat thus prepared (*le corps préparé*) is said to be very stable. Occasionally a simpler method is employed. The purified fat is digested with gum benzoës (*axonge benzoinée*) or with tolu

¹⁾ Comp. S. Piesse, *Chimie des Parfums*. Paris 1897. pp. 59, 60; J.-P. Durville, *Fabrication des Essences et des Parfums*. Paris 1908. p. 77. See also Jeancard et Satie, *Recherches analytiques sur quelques essences de jasmin* [Bull. Soc. chim. III. 23 (1900), 555] and Hesse, *Über ätherisches Jasminblütenöl* [Berl. Berichte 34 (1901), 291].

²⁾ Report of Schimmel & Co. Oktober 1900, 37.



Fig. 62.

Enfleurance (to the left) and défleurance (to the right). Against the walls the piles of châsis.
Parfumeries de Seillans, Dép. du Var, Southern France.

balsam (*axonge toluinée*) or for a few moments only with poplar buds (*axonge populinée*).

The process here described is used almost universally. In a few instances only other "fat bodies" have been used, viz., olive oil or paraffin oil. These also must be of the very best quality, but do not have to be "prepared". Formerly behen oil (from *Moringa pterygosperma*, Gærtn.) was used extensively in southern France. It does not readily become rancid, but an excessive duty now prohibits its use.¹⁾

Paraffin enjoys the advantage over fats because of its indefinite keeping qualities, but is little used for the reason mentioned below. When liquid oils are used, the glass plates of the châssis are replaced by wire screens, which serve as supports for woolen cloths saturated with the oil in question. The flowers are strewn on these cloths. The process is otherwise as described above. The perfumed oil, *huile française*, *huile parfümée*, *huile antique*, is finally expressed from the cloths by means of hydraulic presses. The pure oil is obtained from the pomade or from the *huile française* as from the concrete oils. The pomade is extracted with strong alcohol, either in flasks by continuous shaking or in factories with the aid of special stirring apparatus illustrated in fig. 64. The cylindrical vessels are supplied with mechanical stirring apparatus which cause the fat and alcohol to be intimately mixed. Here also the last traces of fat are removed by freezing. From the *extraits aux fleurs* thus prepared, the *essences* are obtained by removal of the alcohol.²⁾

The residual fat is no longer suited to enfleurage and, as *corps épuisé* finds its way into the soap industry. The waste flowers are used either as fertilizer, or occasionally for the production of *essences concrètes*.

According to Hesse³⁾ the enfleurage with fat is preferable in every way to that with paraffin oil. Comparative experiments have revealed that paraffin has a much lower absorption capacity for odoriferous substances than fat, hence causing a much

¹⁾ Heckel, Rev. cultures coloniales 5 (1901), 258.

²⁾ Jeancard and Satie, *Abrégé de la Chimie des Parfums*. Paris 1904. p. 13.

³⁾ Berl. Berichte 34 (1901), 293 ff.

B. EXTRACTION WITH NON-VOLATILE SOLVENTS.



Fig. 63. On the chérisis held in a diagonal position the chérisis saturated with oil can be seen.

lower yield. Thus the enfleurage of 1000 kilo of jasmine flowers with fat yielded 1684 g of ethereal oil, whereas enfleurage with paraffin yielded but 1053 g oil.¹⁾

PNEUMATIC METHOD. In the course of time a number of so called improvements of the enfleurage process have been tried, however, with but little or no success. Best known of these is the "pneumatic method" of A. Piver.²⁾ It consists in passing a current of air, or better still of indifferent carbon dioxide (CO_2) over the flowers and then through the absorption liquid (liquid fat or alcohol). The current of air carries with it the volatile substances exhaled by the flowers and in turn gives them off to the liquid. The apparatus is so constructed that the gas passes through it, several times. The apparatus possesses the theoretical advantage that the fat does not come into contact with the flowers, thus avoiding loss of fat. Moreover, the use of fat can be circumvented since the *extraits aux fleurs* can be prepared directly. Practically, however, the process does not appear to have been used.

2. EXTRACTION WITH NON-VOLATILE SOLVENTS

WITH THE AID OF HEAT:

INFUSION, MACERATION OR ENFLEURAGE À CHAUD.

As a means of extraction purified animal and vegetable fats such as beef fat, lard, olive oil, sometimes also paraffin oil (comp. p. 260) are used in this process. Paraffin oil, as already mentioned under the enfleurage process, is less adapted since it has a lesser absorption capacity for perfumes than have the fats. However, even solid paraffin (m. p. 66°) is occasionally used. With its aid products are obtained which remain solid even in the tropics, hence do not require special containers for shipment.

The flowers to be extracted either, in bulk or tied into sacks made of fine linen, are immersed in the fat heated to about 50 to 70°. The time of extraction varies with the plant materials and lasts up to 48 hours. The fineness of the aroma of the pomade is inverse to the time of exposure of the flowers to the action of the fat. If prolonged unduly, other odoriferous substances that

¹⁾ According to Hesse, the extraction of 1000 g of jasmine flowers with petroleum ether yields only 178 g of volatile oil. Comp. Berl. Berichte 33 (1900), 1589.

²⁾ Piver's absorption apparatus is illustrated in Wagner's Jahresbericht 1864, p. 490.

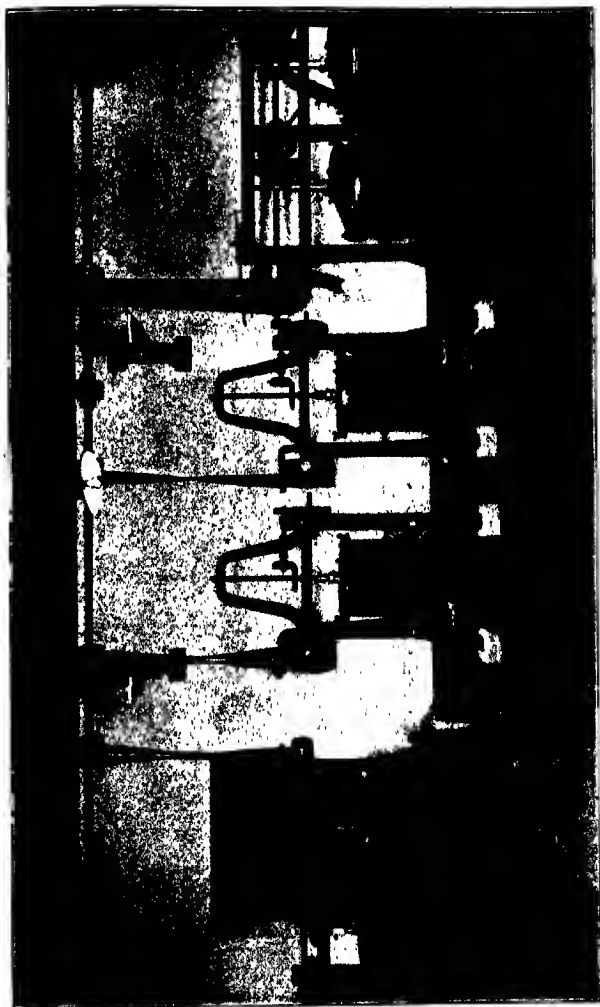


Fig. 64.
Apparatus for the extraction of pomades with alcohol (*Batteuses à extrait*).
Parfumeries de Seillans Dén. du Var. Southern France.

interfere with the quality of the perfume are also absorbed. The extraction being completed, the fat is expressed from the flowers with the aid either of hydraulic presses or of centrifuges (fig. 65, p. 267). The recovered, partly aromatized fat is treated with fresh flowers. This is repeated ten to fifteen times¹⁾ until the fat has acquired the desired strength as to odor. The floral extracts thus obtained are known by the same names as those obtained by the enfleurage process and are treated in like manner for the separation of the volatile oil. Here also the recovered fat, the *corps épuisé*, is not used again in the perfume factory but finds its way into the soap industry.

This process is applied to violets, roses, orange blossoms, lilies of the valley, &c., whereas jasmine, tuberose, and jonquil are not thus treated because of their small yield.

¹⁾ According to Labbé the average is 6 to 8 times. H. Labbé, *Essais des Huiles essentielles*. Paris. p. 11.

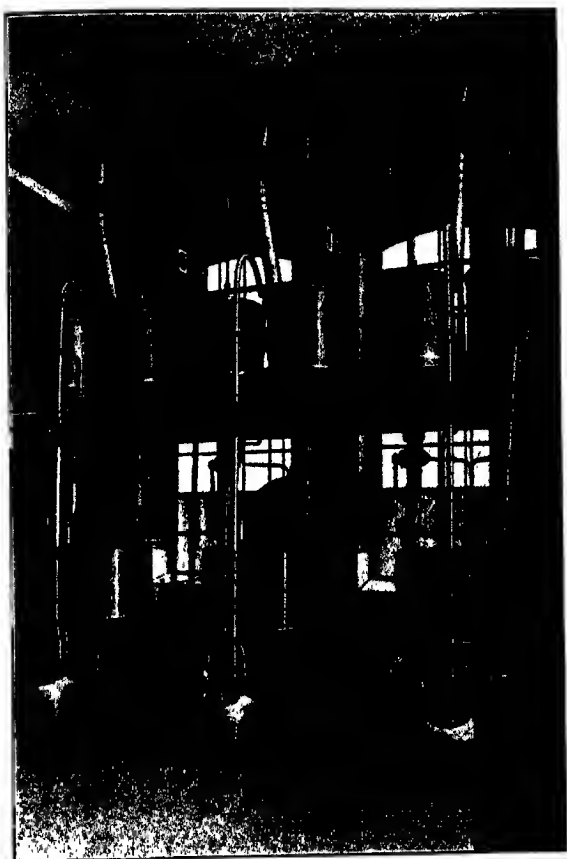


Fig. 65.

Apparatus for maceration and separation of the fat from the flowers by means of centrifuges. Schimmel & Co.



PRINCIPAL CONSTITUENTS OF VOLATILE OILS.

NATURAL AND ARTIFICIAL PERFUMES.



The volatile oils are widely distributed in the vegetable kingdom, more particularly among the phanerogams. However, volatile oils have also been isolated from several of the cryptogams.

In most cases the oils exist preformed in the various organs of the plant, the leaves, flowers, fruits, stems and roots. They occur secreted either in glands or in canal-like, intercellular receptacles. Only a few are formed by hydrolysis during the process of preparation from other substances in the plant, e.g. bitter almond oil from amygdalin, mustard oil from sinigrin. Nothing definite is known with regard to their function or their relation to the other constituents of the plant organism. It appears, however, to be well established that they are excretions formed during the life process of the plant, which are of no further importance in the processes of metabolism. It does not follow from this that they are therefore useless, for they act as a means of attracting insects that bring about fertilization, they also protect plants against enemies. These oils are not definite chemical units, but mixtures of substances belonging to many series and classes of compounds.

Not infrequently the oils obtained from different organs of the same plant differ in their chemical composition and in consequence reveal more or less striking differences in their properties. Thus the oil obtained from the root of the cinnamon shrub differs greatly in its composition from that of the bark, which in turn bears but little resemblance to that from the leaves. Moreover, the oils obtained from the same parts of the same species often reveal considerable differences, which are explained by differences in the stage of development of those parts, or by differences in the conditions of climate and soil. Even from identical material, different oils can be obtained by variation in the method of distillation.

Among the various constituents of an oil, one frequently attracts attention as the principal bearer of the odor. In many instances this constituent is the most valuable. The desire to obtain it in a concentrated and pure form may have given the first impetus to the scientific investigation of essential oils. So long as organic chemistry was in its infancy, these investigations could not be crowned with great success. Only after the methods of investigation had been improved hand in hand with the progress of science, was an insight into the nature of volatile oils obtainable. This insight revealed the fact that the oils are as a rule mixtures of a number of complex substances. How systematic research, more particularly in recent decades has afforded an insight into this field, has been revealed in the historical part. In the following pages the results of investigations are to be recorded so far as they concern the better characterized constituents found in volatile oils. Occasionally reference will also be made to substances that have been obtained only by synthesis. For reasons readily apparent a detailed account of their chemical behavior had to be omitted. Only those properties that pertain to their isolation, recognition and identification are enumerated. For further information the larger handbooks of organic chemistry will have to be consulted. To all who are concerned with the scientific investigation of volatile oils, the classic work of Otto Wallach¹⁾ "*Terpene und Campher*", also the detailed handbook of Semmler²⁾ will prove particularly useful. The latter affords a ready oversight over the enormous literature on the constituents of volatile oils, and discusses in detail all constituents found in volatile oils and not only particular classes of compounds.

The analysis of a volatile oil is difficult because most of the constituents are liquid, and can, therefore, be separated only by fractional distillation. This operation, imperfect at best, is often rendered more unsatisfactory by the fact that certain constituents are not volatile without decomposition. For this and

¹⁾ O. Wallach, *Terpene und Campher. Zusammenfassung eigener Untersuchungen a. d. Gebiete der alicyclischen Kohlenstoffverbindungen.* Leipzig 1909.

²⁾ F. W. Semmler, *Die ätherischen Öle nach ihren chemischen Bestandteilen.* Leipzig 1906 1907.

other reasons it is best to subject an oil to a preliminary examination, the results of which often suggest modifications which simplify the examination considerably. The preliminary examination consists primarily in the determination of the physical properties of the oil and of its elementary composition; also in a study of the behavior of the oil toward certain group reagents, whereby the presence or absence of certain classes of chemical compounds can be ascertained.

Of the physical constants, the specific gravity, the optical properties and the behavior of an oil toward heat and cold allow conclusions to be drawn as to its composition. A specific gravity, e. g. of less than 0,90 indicates the presence of a large amount of terpenes or of compounds of the fatty series. The oil of *Pinus Sabiniana* with $d_{15} = 0,70$, heracleum oil with $d_{15} = 0,80$ to 0,88 and oil of rue with $d_{15} = 0,833$ to 0,840 belong to those with a very low specific gravity. These consist mainly of derivatives of the fatty series. Oil of orange, sp. gr. 0,848 to 0,857, consists largely of the terpene limonene; turpentine oil, with a specific gravity of 0,850 to 0,875, almost completely of hydrocarbons $C_{10}H_{16}$ of the terpene series. A specific gravity higher than 0,90, as is the case with most oils, indicates a mixture of several classes of compounds; whereas a specific gravity of more than 1,0 indicates the presence of compounds of the aromatic series, or if the compound contains sulphur or nitrogen, of sulphides, nitriles or isosulphocyanides.

The optical properties, rotation and refraction, are of less importance unless pure chemical compounds are to be examined or adulterations to be looked for. The optical activity of an oil indicates the presence of a compound or compounds with one or more asymmetric carbon atoms; a high index of refraction the presence of a substance or substances with double bonds, thus enabling the investigator to draw conclusions as to the presence of aliphatic, cyclic or dicyclic compounds.

When exposed to low temperatures, a number of oils deposit one or more of their constituents in crystalline form. Some oils, like rose oil, contain crystals even at ordinary temperature, others, like orris oil and oil of ambrette seeds are butyraceous in consistency. These substances have been designated stearoptenes or camphors and are paraffins, higher members of the

series of fatty acids, such as lauric, myristic and palmitic acids, and derivatives of aromatic and hydroaromatic hydrocarbons. As an exception the methyl nonyl ketone of oil of rue should be mentioned.

Most oils, in case they can be distilled under ordinary pressure without decomposition, begin to boil above 150°. Exceptions to this rule are *e. g.* those containing sulphur, and such volatile oils which, like the distillation product of the turpentine from *Pinus Sabiniana* or the oil of *Pittosporum resiniferum*, contain low boiling hydrocarbons of the paraffin or olefin series. In the absence of oxygenated constituents, a boiling point below 200° indicates the presence of terpenes, between 250 and 280° that of sesquiterpenes, above 300° of polyterpenes.

In their elementary composition the volatile oils do not manifest great variety. All contain carbon and hydrogen; most of them also contain oxygen in larger or smaller quantity; few contain nitrogen or sulphur, or both. The presence or absence of oxygen can be determined by elementary analysis only. The presence of only a small amount of this element, up to 5 p. c., indicates a high hydrocarbon content. The presence of sulphur, which can be oxidized in sealed tubes to sulphuric acid by means of concentrated nitric acid indicates mustard oils, sulphides, or polysulphides. Nitrogenous compounds are converted into cyanides by heating with metallic sodium or potassium and are recognized by means of the Prussian blue reaction. The nitrogen content of an oil is mostly due to nitriles. If sulphur is also found, mustard oils are present which, as a rule, betray their presence by their characteristic odor.

After the elementary composition of an oil has been ascertained, a few group reagents can be applied to learn whether special attention should be given to one class or another of chemical compounds.

If an oil shows an acid reaction, it contains acids or phenols. Small amounts of fatty acids occur occasionally as decomposition products of esters present. Larger amounts reveal their presence by the diminution of volume when the oil is shaken with an aqueous solution of caustic or carbonated alkali. The presence of an ester or lactone can be ascertained when an oil is heated with alcoholic potassa of known strength and titrated

back with standard acid. This test presupposes the absence of free acids and aldehydes. Alcohols can be converted into acetic esters by heating the oil with acetic acid anhydride. Subsequent saponification will then reveal the presence or absence of an alcohol in the oil. Aldehydes and ketones can be recognized by their addition products with alkali bisulphites, or by their condensation products with hydroxylamine or semicarbazide in aqueous alcoholic solution. The latter contain nitrogen and as a rule are difficultly volatile with water vapor. Ethers, which are sometimes present as phenol ethers, can be recognized by means of Zeisel's method.

After these preliminary tests have revealed the presence of a substance belonging to one of the above mentioned classes, it is sometimes possible to separate it without fractional distillation; provided, however, that this method of separation does not change the other constituents of the oil. The analysis of the oil having been thus simplified, fractionation of the non-reacting portion can be resorted to. It should also be noted that these methods of separation never effect a perfect isolation because the other constituents of the oil prevent a part of the substance to be isolated from reacting. When, therefore, the non-reacting portion of the oil is fractionated small amounts of this substance should not be overlooked. Thus it is possible with these group reagents to separate aldehydes and many ketones with acid sulphite solution—a reaction that can at times be facilitated by the addition of alcohol. The crystalline addition product is washed with alcohol and ether and the aldehyde or ketone regenerated by the addition of alkali or dilute acid. Free acids and phenols can be shaken out with aqueous alkali; indifferent substances are then removed from the aqueous solution by shaking it with ether, and then the acid or phenol is set free with dilute mineral acid. If acids and phenols are both present, the former are separated with carbonate solution. Basic substances, such as indole and anthranilic esters can be separated by shaking out with dilute acids. Lactones yield salts of the corresponding hydroxyacids when heated with alcoholic potassa. They are precipitated from the alkaline solution as lactones or hydroxyacids by the addition of a mineral acid. Esters if present are saponified by this treatment with alkali. Aldehydes and ketones,

however, are modified thereby and at times destroyed. Sulphur derivatives can often be isolated in the form of their mercury compounds or as thioureas.

If none of these short cuts is possible, the oil is fractionated either under ordinary or diminished pressure. If esters are present, the oil is first saponified. It may be taken for granted that the apparatus to be used and the methods to be employed are known. A good guide for distillation under diminished pressure will be found in a small monograph on this subject by Anschütz.¹⁾ The various fractions obtained upon a careful fractionation are examined for compounds, in part according to the methods already mentioned. A trained sense of smell will prove an important additional factor. Suspected compounds are, if possible, converted into crystalline derivatives and thus purified and identified.

Ketones that will not combine with acid sulphites, such as menthone, camphor, fenchone, carvone, are converted into oximes or semicarbazones. Inasmuch as the oximes frequently suffer rearrangement with acids, the semicarbazones are at times to be preferred because the ketones can in most cases be regenerated. Certain ketones, such as carvone and pulegone, can be separated by means of their sodium sulphite compounds.

Alcohols are characterized by their capacity to form esters, also phenylurethanes with phenylisocyanate (carbanil). They can be purified by means of difficultly volatile esters of monobasic acids, such as benzoic acid; or by means of acid esters of dibasic acids, such as succinic acid, phthalic acid, etc. Some of the primary alcohols can also be purified by converting them into calcium chloride addition products from which they are easily regenerated by means of water.

From the hydrocarbons traces of oxygenated compounds can be removed by repeated treatment with metallic sodium. If low boiling hydrocarbons are to be distilled under diminished pressure, a liquid alloy of potassium and sodium is preferable.

As to the compounds themselves that are found in volatile oils, they belong in part to the aliphatic, in part to the aromatic and hydroaromatic series and are distributed over a large

¹⁾ *Die Destillation unter vermindertem Druck*. 2. ed. Bonn 1895.

number of classes. The hydrocarbons, especially those of the formula $C_{10}H_{18}$, are widely distributed. Of greater importance, however, are the oxygenated substances, because they are mostly the bearers of the characteristic odor of the oil in which they are contained. In addition to the hydrocarbons there have been found alcohols, aldehydes, acids, esters, ketones, phenols, phenol-ethers, lactones, quinones, and oxides; further, bases, sulphides, mercaptanes, nitriles, and isothiocyanates.

HYDROCARBONS.

A. ALIPHATIC HYDROCARBONS.

The lowest member of the limit series of hydrocarbons C_nH_{2n+2} which has been found in volatile oils is the normal heptane, C_7H_{16} (b. p. 98,5 to 99 ; d_{16} 0,6880). In addition to minimal amounts of other substances, it has been obtained by the distillation of the oleoresin of *Pinus Sabiniana* and *P. Jellreyi*, both of which are found in California, also by the distillation of the fruits of *Pittosporum resiniferum*.

The higher members of the paraffin, and probably of the olefin series also, appear to be quite widely distributed in the vegetable kingdom. They constitute the wax-like coating and secretions on leaves, flowers, fruits etc. In volatile oils, however, they are not met with commonly because of their sparing volatility. Sometimes they separate in crystalline form when the oil is exposed to a low temperature, or they remain behind upon fractional distillation. In the oils of rose and chamomile, however, the amount of paraffin is so large, that the oil congeals even at middle temperature. Apparently these hydrocarbons seldom occur alone, but as mixtures of homologues as has been shown in the case of rose oil. Their melting points seldom if ever agree with those of known members of the series. With the exception of the heptane referred to, they are obtained principally as white, colorless, laminar-crystalline masses which are with difficulty soluble in cold alcohol, but readily soluble in hot alcohol

and other organic solvents. They are remarkable on account of their stability toward concentrated acids and oxidizing agents at ordinary temperatures.

The rose oil scaroptene melts at 35° and, when distilled in a vacuum, can be resolved into two fractions melting at 22° and 40–41° respectively. In addition to this solid mixture, paraffin or olefin hydrocarbons have been found more particularly in the oils distilled from flowers. The paraffins thus far isolated are recorded, with their melting points, in the following table:

| | |
|---|-----------------|
| Oil of <i>Kæmpheria Galanga</i> | m. p. 10° |
| Oil of poplar buds, a mixture of homologous paraffins with the melting points 53 to 54, 57 to 58, 62 to 63, 67 to 68° | |
| Oil of birch buds | m. p. 50° |
| Oil of hemp | m. p. 63 to 64° |
| Oil of sassafras leaves | m. p. 58° |
| Oil of pelargonium | m. p. 63° |
| Oil of jaborandi leaves | m. p. 28 to 29° |
| Oil of neroli (aurade) | m. p. 55° |
| Oil of <i>Evodia simplex</i> | m. p. 80 to 81° |
| Oil of several <i>Cistus</i> species | m. p. 64° |
| Oil of caraway herb | m. p. 64° |
| Oil of dill | m. p. 64° |
| Oil of wintergreen (both <i>Betula</i> and <i>Gaultheria</i>) | m. p. 65,5° |
| Oil of verbenä | m. p. 62,5° |
| Oil of <i>Helichrysum angustilolium</i> | m. p. 67° |
| Oil of Roman chamomile | m. p. 63 to 64° |
| Oil of German chamomile | m. p. 53 to 54° |
| Oil of <i>Chrysanthemum cinerariæfolium</i> | m. p. 64° |
| Oil of arnica flowers | m. p. 63° |

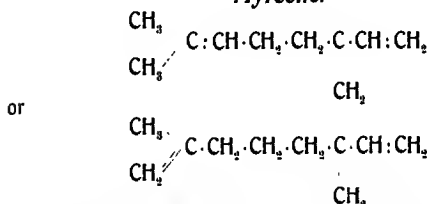
Additional occurrences of the paraffins have been established in the oils from species of *Spiræa* and *Turnera*, in oil of chervil, in the oil of elderblossoms, the oils of *Monarda didyma*, of *Inula viscosa* and others.

Olefinic hydrocarbons, the octylenc, C_8H_{16} (m. p. 123 to 124°; $d_{40} 0,7275$; $n_D^{20} 1,4066$) only has been found thus far, viz., in the oils of bergamot and lemon. Possibly it also occurs in

linaloe oil. Isoprene, C_5H_8 , interesting because of its relation to the terpenes, has been observed only as decomposition product of caoutchouc and turpentine oil.

However, chain hydrocarbons of the formula of saturation C_nH_{2n-4} with three double bonds have been found. In composition they agree with the terpenes but differ in having a lower specific gravity and a lower index of refraction. These hydrocarbons, which have been termed "olefinic terpenes" by Semmler, show a great tendency to resinify, especially when distilled under ordinary pressure.

Myrcene.



The first representative of this class was found in oil of bay by Power and Kleber¹⁾ and named myrcene. Later its presence in the first fractions of the oil of *Lippia citriodora* was ascertained. Probably it also occurs in West Indian lemongrass oil and in oil of linaloes. Barbier found myrcene among the dehydration products of linalool. Its constitution has not yet been definitely determined, but probably finds expression in one of the above formulas. The following constants have been recorded:

| | b. p. | b. p. (20 mm) | d_{15}^4 | n_D^{20} |
|--------------------------------|-------------|---------------|------------|-----------------|
| Power and Kleber ¹⁾ | 167° | 67 to 68° | 0,8023 | 1,4673 |
| Semmler ²⁾ | 171 to 172° | 67 to 68° | — | 1,4673 |
| Enklaar ³⁾ | 166 to 168° | — | 0,8013 | 1,4700 (at 19°) |

According to Semmler, myrcene, upon reduction with sodium and alcohol, yields dihydromyrcene, $C_{10}H_{18}$, a liquid possessing

¹⁾ Pharm. Rundsch. (New York) 18 (1895), 61.

²⁾ Berl. Berichte 34 (1901), 3126.

³⁾ Over Ocimeen en Myrcen, *Eene Bijdrage tot de kennis van de aliphatische Terpenen*. Inaug.-Dissert., Utrecht 1905.

the following properties: b. p. 171,5 to 173,5°, $d_{20} 0,7802$, $n_D^{20} 1,4501$ (Semmler).¹⁾ B. p. 167 to 169° (corr. at 770 mm), $d_{16} 0,7852$, $n_D^{16} 1,4514$ (Enklaar). From the dihydromyrcene Enklaar prepared a tetrabromide melting at 88°.

Upon hydration of myrcene with glacial acetic acid and sulphuric acid at 40° according to Bertram's method,¹⁾ Power and Kleber obtained an acetate with an odor reminding of lavender. Upon saponification it yielded, in their opinion, linalool. Barbier,²⁾ however, supposed that the hydration yielded a new alcohol which he named myrcenol. From myrcenol Enklaar (*l. c.*) obtained a crystalline phenylurethane, m. p. 68°, which differs from that obtained from linalool. According to Enklaar, myrcenol has the following constants: b. p. 99° (10 mm), $d_{15} 0,9032$, $n_D^{15} 1,4806$.

Potassium permanganate oxidizes myrcene to succinic acid. Myrcene can be identified by means of the dihydromyrcene mentioned above, also, according to Enklaar, by means of the dihydromyrcene tetrabromide, m. p. 88°. Myrcene polymerises readily to dimyrcene, which is characterized by a nitrosite that decomposes at 163°.

Ocimene.

This aliphatic terpene is isomeric with myrcene. It differs from the latter, presumably, in the position of the double bonds. It was discovered by van Romburgh in the oil of *Ocimum Basilicum*. Possibly it is also contained in esdragon oil. B. p. 73 to 74° (21 mm); $d_{20} 0,794$; $d_{15} 0,801$; $n_D^{15} 1,4861$.

The dihydro-ocimene, which results upon reduction with sodium and alcohol, is identical with dihydromyrcene.

Upon hydration, according to Bertram's method,³⁾ Enklaar obtained ocimenol [b. p. 97 (10 mm); $d_{15} 0,901$; $n_D^{15} 1,4900$], which yields a phenylurethane melting at 72°.

Upon heating, ocimene yields allo-ocimene, which possibly is stereoisomeric with ocimene. The physical constants are somewhat higher than those of ocimene: b. p. 81° (12 mm), $d_{15} 0,8182$, $n_D^{15} 1,5296$.

Additional aliphatic terpenes have been found in hop oil,⁴⁾

¹⁾ Berl. Berichte 34 (1901), 3126.

²⁾ Compt. rend. 132 (1901), 1048; Bull. Soc. chim. III, 25 (1901), 687.

³⁾ D.R.P. 67255.

⁴⁾ Chapman, Journ. chem. Soc. 67 (1895), 54.

in the oil of Indian hemp (*Cannabis indica*)¹⁾, in the oil of sassafras leaves,²⁾ in rosemary oil³⁾, and in the origanum oil of Smyrna.⁴⁾

Mention should also be made of the occurrence of an olefinic sesquiterpene $C_{15}H_{24}$ ⁵⁾ in oil of citronella. Its constants are: b. p. 270 to 280° (atmospheric pressure), 157° (15 mm); $d_{15} = 0.8643$; $n_{D15} + 1^{\circ}28'$; $n_{D15} = 1.51849$.

B. AROMATIC HYDROCARBONS.

From the oil of the mammoth fir, *Sequoia gigantea*, Lunge and Steinkauler⁶⁾ obtained a hydrocarbon $C_{13}H_{10}$ which they named sequoiene. It consists of laminar crystals, with a reddish fluorescence, that melt at 105° and boil between 290 to 300° (uncorr.). It has not been identified with any of the known hydrocarbons of like composition, such as fluorene etc. With picric acid an addition product of red crystalline needles results.

Noteworthy is also the occurrence of naphthalene which has been found in an oil of clove stems, in the oil of a storax bark, and in orris oil. It is readily characterized by its melting point (79 to 80°), its boiling point (218°), and by a picrate that melts at 149°.

Styrene.

CH

HC CH

HC CH

C-CH:CH₂

The simplest aromatic hydrocarbon with an unsaturated side chain that is found in volatile oils is styrene (vinyl benzene). It occurs in storax oils and in xanthorrhoea resin oil. It is probably formed by the decomposition of cinnamic acid.

¹⁾ Journ. chem. Soc. 69 (1896), 539.

²⁾ Report of Schimmel & Co. April 1896, 66.

³⁾ Arch. der Pharm. 235 (1897), 585.

⁴⁾ Gildemeister, Arch. der Pharm. 233 (1895), 184.

⁵⁾ Report of Schimmel & Co. October 1899, 23.

⁶⁾ Berl. Berichte 13 (1880), 1656; 14 (1881), 2202.

Styrene is a colorless, highly refractory liquid of a pleasant odor, which polymerizes to a transparent, glasslike and odorless mass, mctastyrne (C_8H_8)_n, by being kept for some time, and more rapidly by heating, or by contact with acids.

As to its physical properties, the following statements have been recorded:

B. p. 144 to 144,5°.¹)

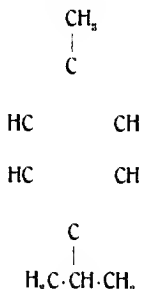
B. p. 140° (760 mm); $d_{20} = 0,9074$; $n_D^{20} 1,54030$.²)

B. p. 146,2°; $d_{20} 0,9251$,³) $d_4^{17} 0,90595$; $n_D 1,54344$.⁴)

Pure styrene is optically inactive. Dilute nitric acid or chromic acid mixture oxidize it to benzoic acid. Upon reduction it yields ethyl benzene.

For identifying styrene the well crystallized styrene dibromide $C_8H_8 \cdot CHBr \cdot CH_2Br$ is used, and is obtained by allowing bromine (17 parts) to drop into a solution of the hydrocarbon (10 parts) in twice its volume of ether.⁵) On evaporation, the bromide separates in crystals, which after being recrystallized from 80 percent alcohol have the melting point 74—74,5°.

p-Cymene.



Of the hydrocarbons designated as cymenes $C_{10}H_{14}$, only the *meta* and *para* compounds are of importance to the chemistry

¹) Observations made in the laboratory of Schimmel & Co.

²) Brühl, Liebig's Annalen 235 (1886), 13.

³) Weger, Liebig's Annalen 221 (1883), 69.

⁴) Nasini and Bernhelmer, Gazz. chim. ital. 15 (1885), 59; Jahresber. d. Chem. 1886, 314.

⁵) Zincke, Liebig's Annalen 216 (1883), 288.

of the volatile oils. While *m*-cymene has been observed only as a decomposition or "Abbau" product (Kelbc, dry distillation of colophony; Wallach, dehydration of fenchone; Baeyer, splitting off hydrogen from sylvestrene), *p*-cymene is a frequent constituent of volatile oils. Up to the present it has been found in Swedish and Russian turpentine oils, in the oil of *Cupressus sempervirens*, in staranise oil, oil of nutmeg, oil of boldo leaves, oil of Ceylon cinnamon, oil of Seychelle cinnamon bark, cascarilla oil, lemon oil, in the oil of *Canarium Cumingii*, in the oil of *Eucalyptus hæmastoma*, in oil of ajowan, in coriander oil, in cumin oil, in the oil of *Cicuta virosa*, in angelica root oil, in the oils of *Monarda punctata* and *M. listulosa*, *Satureja hortensis*, *S. Thymbra*, in the origanum oils from Triest, Smyrna, and Cyprus, in sage oil, in the oils of *Thymus vulgaris*, *Th. Serpyllum*, *Th. capitatus*, and in American wormseed oil.

Like *m*-cymene, *p*-cymene has frequently been obtained as a transformation product, e. g. from pinene, terpinene, cumin alcohol, laurus camphor, sabinol, thujone, carvenone, dihydrocarvone, carvone, and citral.

The mixture of hydrocarbons known as "thymene", obtained from ajowan oil and used as a soap perfume, consists principally of cymene together with several terpenes (see ajowan oil).

Formerly it was thought that all terpenes were related to this hydrocarbon, that they were its hydroderivatives. According to recent investigations, however, this conception is not wholly correct. It is worthy of mention, that several compounds of the formula $C_{10}H_{16}O$ can be changed to *p*-cymene by the abstraction of water, for instance, camphor and citral.

Cymene is a colorless liquid with an agreeable odor.

B. p. 175 to 176°; d_{15}^{20} , 0.8602.¹⁾

B. p. 175.2 to 175.9° (752 mm); d_{15}^{20} , 0.8551; n_D^{20} , 1.48456.²⁾

B. p. 173.5 to 174.5° (763 mm); d_{15}^{20} , 0.8595; d_{15}^{20} , 0.8588; n_D^{20} , 1.479.³⁾

¹⁾ Widmann, Berl. Berichte 24 (1891), 452.

²⁾ Brühl, Berl. Berichte 25 (1892), 172.

³⁾ Wolplan, Pharm. Zeitschr. f. Russl. 35 (1896), 115.

The following constants were observed in the laboratory of Schimmel & Co. in connection with a preparation obtained from camphor:

B. p. 174,5 to 176 (761 mm); d_{15} 0,863; $n_{D,15}$ 1,49015.

The pure hydrocarbon is optically inactive. Dilute nitric acid also chromic acid mixture oxidize it to *p*-toluic acid and finally to terephthalic acid. Potassium permanganate attacks it with difficulty. Hence terpenes having a like boiling point can be removed by treating it with dilute permanganate solution in the cold. Should cineol, which boils at the same temperature, be present, it can be removed as its hydrogen bromide addition product. For its identification, cymene is converted into *p*-hydroxyisopropylbenzoic acid (m. p. 155 to 156°) with the aid of concentrated, hot potassium permanganate solution. This acid, when heated with dilute hydrochloric acid, splits off water yielding *p*-isopropenylbenzoic acid (m. p. 160 to 161°); when boiled with concentrated hydrochloric acid it yields an isomeric acid with a boiling point of 255 to 260°.¹) For the preparation of hydroxyisopropylbenzoic acid Wallach²) has given the following directions: 2 g. at a time of the hydrocarbon, prepared as pure as possible, are heated with a solution of 12 g. of potassium permanganate in 330 g. of water on a water-bath with reflux condenser, the mixture being frequently agitated. When the oxidation is complete, the filtrate from the oxides of manganese is evaporated to dryness and the saline residue boiled with alcohol. The potassium salt which is soluble in the alcohol, is decomposed in aqueous solution with dilute sulphuric acid, and the precipitated acid recrystallized from alcohol.

The sulphonic acid, produced by treating the hydrocarbon with concentrated sulphuric acid, is also characteristic for cymene. Its barium salt $(C_{10}H_{12} \cdot SO_3)_2Ba$ crystallizes in shining, difficultly soluble laminae and contains three molecules of water of crystallization which can be completely driven off at 100°. The sulphone amide which can be prepared from the

¹) R. Meyer and Rosicki, Liebig's Annalen 219 (1883), 282.

²) Liebig's Annalen 264 (1891), 10.

chloride of this sulphonic acid melts at 115 to 116°. That cymene sulphonic acid may also result from the action of sulphuric acid on different terpenes must, however, be remembered, also that an isomeric acid is formed at the same time.

C. ALICYCLIC HYDROCARBONS.

The principal hydrocarbons occurring in volatile oils are alicyclic. The composition of by far the greater number is represented by the formula $C_{10}H_{16}$, hence they belong to that class of the terpenes in which the carbon atoms are arranged in a cycle. As to their formation in the plant organism nothing definite is known. Possibly they are genetically related to oxygenated chain compounds $C_{10}H_{16}O$, since these yield artificially hydrocarbons $C_{10}H_{16}$ upon dehydration. Possibly they are formed from carbohydrates or proteins. It is noteworthy, however, that the terpene content of an oil is greater, the less developed the plant at the time of distillation.

The majority of the known hydrocarbons of the terpene group are found ready formed in nature. Thus the presence of α - and β -pinene, camphene, limonene, dipentene, terpinolene, α - and γ -terpinene, α - and β -phellandrene, sylvestrene, and sabinene has been definitely established. With the exception of the inactive terpinene and terpinolene, these hydrocarbons exist, for the most part, in both optically active forms.

In as much as it is frequently necessary to work with small amounts, it is often impossible to isolate the terpenes in pure form by means of fractional distillation. As a rule it suffices to remove oxygenated compounds from the fraction 150 to 180° by repeated distillation over sodium. A further separation can be effected by distillation since the bicyclic hydrocarbons boil between the temperatures of 150 and 170°, the monocyclic between 170 and 180°. Both classes of terpenes also reveal appreciable differences in their molecular refraction. The physical constants having been determined, more or less definite conclusions can be drawn as to the nature of the terpenes under investigation, thus leading to the preparation of derivatives characteristic of the hydrocarbons in question. These derivatives are described in connection with the respective hydrocarbons.

Owing to the complicated structure of their molecules, also to the readiness with which these are inverted into isomeric forms, the synthesis of the terpenes and sesquiterpenes has been coupled with difficulties. A single compound is obtained but seldom, the principal product being associated with a mixture of several isomers. The following compilation of the synthesis, or more correctly artificial preparation, of the hydrocarbons makes no claim as to completeness. In each group the best known representatives only are enumerated.

I. DIHYDRATION OF TERPENE- AND SESQUITERPENE ALCOHOLS.

| | |
|-----------------------|--|
| α -Terpineol | > Dipentene ¹⁾ |
| γ -Terpineol | > Terpinolene ²⁾ |
| Terpinenol-4 | > Terpinene ³⁾ |
| Dihydrocarveol | > Limonene, Isolimonene, ⁴⁾ Terpinene ⁵⁾ |
| Borneol | > Camphene ⁶⁾ |
| Isoborneol | |
| Fenchylalcohol | > Fenchene ⁷⁾ |
| Isofenchylalcohol | |
| Pinocampicol | > α -Pinene ⁸⁾ |
| Cedrol | > Cedrene ⁹⁾ |
| Maaliolalcohol | > Maalisesquiterpene ¹⁰⁾ |
| Caryophyllene alcohol | > Clovene. ¹¹⁾ |

II. DIHYDRATION OF KETONES.

| | | | |
|---------|-----------------------------------|----------|------------------------------------|
| Camphor | > <i>p</i> -Cymene ¹²⁾ | Fenchone | > <i>m</i> -Cymene. ¹³⁾ |
|---------|-----------------------------------|----------|------------------------------------|

¹⁾ Wallach, Liebig's Annalen 230 (1885), 265; 275 (1893), 104; 291 (1896), 361.

²⁾ Wallach, *Ibidem* 368 (1909), 10.

³⁾ Report of Schimmel & Co. October 1900, 72.

⁴⁾ Tschugaeff, Berl. Berichte 33 (1900), 735.

⁵⁾ Wallach, *Ibidem* 24 (1891), 3984; Liebig's Annalen 275 (1893), 113.

⁶⁾ Wallach, Liebig's Annalen 230 (1885), 233; Bertram and Walbaum, Journ. f. prakt. Chem. II. 48 (1894), 8.

⁷⁾ Wallach, Liebig's Annalen 284 (1895), 331; Bertram and Helle, Journ. f. prakt. Chem. II. 41 (1900), 298; Tschugaeff, Chem. Ztg. 24 (1900), 542.

⁸⁾ Tschugaeff, Journ. russ. phys. chem. Ges. 30 (1906), 1324; Gildemeister and Köhler, Wallach-Festschrift, Göttingen 1909, p. 136.

⁹⁾ Report of Schimmel & Co. October 1904, 24.

¹⁰⁾ *Ibidem* November 1908, 137.

¹¹⁾ Wallach, Liebig's Annalen 271 (1892), 294.

¹²⁾ Fittica, *Ibidem* 172 (1874), 307.

¹³⁾ Wallach, *Ibidem* 275 (1893), 157; 284 (1895), 324.

III. DEAMMONIATION OF BASES.

| | |
|----------------------|-----------------------------------|
| Carvenylamine | > Terpinene ¹⁾ |
| Thujylamine | > Thujene ²⁾ |
| Carylamine | > Carvestrene ³⁾ |
| Phellandrene diamine | > <i>p</i> -Cymene. ⁴⁾ |

IV. BY SPLITTING OFF HYDROHALOGEN.

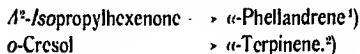
| | |
|----------------------------|--|
| Dipentene dichlorhydrate | > Dipentene ⁵⁾ |
| Terpinene dichlorhydrate | > Terpinene ⁶⁾ |
| Sylvestrene dichlorhydrate | > Sylvestrene ⁷⁾ |
| Bornylchloride | > Camphene ⁸⁾ |
| Monochlorocarvenene | > Terpinene ⁹⁾ |
| Cadinene dichlorhydrate | > Cadinene ¹⁰⁾ |
| Limonene tetrabromide | > { Limonene ¹¹⁾ <i>p</i> -Cymene ¹²⁾ |
| Pinene dibromide | > Cymene. ¹³⁾ |

V. BY SPLITTING OFF CARBON DIOXIDE FROM ACIDS.

| | |
|--|--|
| Nopinolacetic acid | > { α -Pinene ¹⁴⁾ β -Pinene Fenchene |
| Acid from sabinaketone and bromoacetic ester | > β -Terpinene ¹⁵⁾ |
| Bromocamphane carboxylic acid | > Bornylene. ¹⁶⁾ |

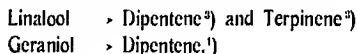
¹⁾ Harries and Majima, Berl. Berichte 41 (1908), 2516.²⁾ Wallach, Liebig's Annalen 272 (1893), 111; 296 (1895), 99.³⁾ Baeyer, Berl. Berichte 27 (1894), 3486; Baeyer and Villiger, *Ibidem* 31 (1898), 1402; comp. Semmler, *Ibidem* 34 (1901), 717.⁴⁾ Wallach, *Ibidem* 324 (1902), 276.⁵⁾ Wallach, *Terpene und Campher*. Leipzig 1909, p. 84.⁶⁾ Wallach, Liebig's Annalen 350 (1906), 148.⁷⁾ Wallach, *Ibidem* 290 (1885), 243, 270.⁸⁾ Wallach, *Ibidem* 290 (1885), 233.⁹⁾ Semmler, Berl. Berichte 41 (1908), 4474; 42 (1909) 522.¹⁰⁾ Wallach, Liebig's Annalen 288 (1887), 84; 271 (1892), 297.¹¹⁾ Godlewsky and Roshanowitsch, Journ. russ. phys. chem. Ges. 81 (1899), 209.¹²⁾ Wallach, Liebig's Annalen 264 (1891), 21.¹³⁾ Wallach, *Ibidem* 264 (1891), 9.¹⁴⁾ Wallach, *Ibidem* 363 (1908), 1; 368 (1909), 1.¹⁵⁾ Wallach, *Ibidem* 357 (1907), 68; 362 (1908), 285.¹⁶⁾ Bredt, *Ibidem* 366 (1909), 46.

VI. SYNTHESIS WITH THE AID OF GRIGNARD'S REACTION.

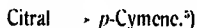


VII. RING-FORMATION ACCOMPANIED BY DEHYDRATION.

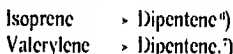
a) from aliphatic terpene alcohols:



b) from aliphatic terpene aldehydes:



VIII. POLYMERISATION OF HYDROCARBONS.



IX. COMPLETE SYNTHESSES.

In addition to the syntheses accomplished by Wallach⁹⁾ with the aid of ketones and bromacetic ester and its homologues, the following may here be mentioned: viz., the synthesis of *Δ^{1,4}*-menthadiene from succinyl succinic acid by v. Baeyer,¹⁰⁾ that of dipentene¹¹⁾ and carvestrene¹²⁾ by Perkin jun. and the more recent syntheses of Komppa in the camphor group.¹³⁾

¹⁾ Wallach, Liebig's Annalen 359 (1908), 283.

²⁾ Auwers and v. d. Heyden, Berl. Berichte 42 (1909), 2404.

³⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 45 (1892), 601.

⁴⁾ Bertram and Gildemeister, *Ibidem* II. 49 (1894), 194; Tiemann and Schmidt, Berl. Berichte 28 (1895), 2134.

⁵⁾ Tiemann and Semmler, Berl. Berichte 28 (1895), 2134.

⁶⁾ Tilden, Journ. chem. Soc. 45 (1884), 410; Bouchardat, Compt. rend. 80 (1875), 1446; 87 (1878), 654; 89 (1879), 361, 1117.

⁷⁾ Bouchardat, Bull. Soc. chim. II. 33 (1880), 24.

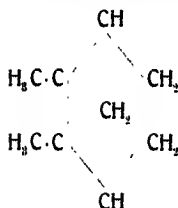
⁸⁾ Wallach, *Terpene und Campher*. Leipzig 1904, p. 145.

⁹⁾ Berl. Berichte 26 (1893), 232.

¹⁰⁾ Journ. chem. Soc. 85 (1904), 654.

¹¹⁾ *Ibidem* 91 (1907), 480.

¹²⁾ Liebig's Annalen 368 (1909), 110; 370 (1909), 209.

Santene == *Norcamphene*.

First of all there may be mentioned a lower homologue of the terpenes, the santene, $C_{10}H_{16}$, which has been observed repeatedly in recent years. Its occurrence has been observed in East-Indian sandalwood oil, in Siberian pine-needle oil, in the German *Fichtennadelöl*, in the needle oil of the German *Abies alba* and in the Swedish *Fichtennadelöl* from *Picea excelsa*. The following constants of this oil have been recorded:

B. p. 31 to 33° (9 mm); d_{20}^4 0.863; n_D^{20} 1.46658.¹⁾

B. p. 140°; d_{15}^{20} 0.8698; n_D^{20} 1.46960.²⁾

Upon hydration with the acetic acid-sulphuric acid mixture according to Bertrain, santene is converted into a bicyclic saturated alcohol, the santenol (*1-norbornol*), h. p. 195 to 196°; m. p. 97 to 98°. When treated with chlorinating agents this yields *norbornyl* chloride, respectively *norisobornyl* chloride. By splitting off hydrogen chloride from these chlorides, Semmler³⁾ obtained *norcamphene*, which is identical with santene.

Characteristic derivatives of santene are its nitrosochloride, m. p. 109 to 110°; its chlorhydrate, m. p. 80 to 81°; its tribromide, m. p. 62 to 63°; and its nitrosite, m. p. 124 to 125°. For its identification Semmler suggests its tribromide. However, according to Aschan's observations, the santenes of different sources yield tribromides with varying melting points. Hence Aschan considers the nitrosite as better adapted for the identification of santene. As a further derivative suitable for the identification of santene,

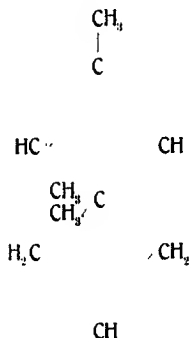
¹⁾ Semmler, Berl. Berichte 40 (1907), 4595.

²⁾ Aschan, Berl. Berichte 40 (1907), 4920.

³⁾ Berl. Berichte 41 (1908), 128.

Semmler and Bartelt¹⁾ mention the santene glycol (m. p. 197°; b. p. 135° at 10 mm), which is obtained by careful oxidation of the hydrocarbon in acetone solution with potassium permanganate.

α-Pinene.



α-Pinene is very widely distributed and occurs in the inactive as well as in both optically active forms. Whereas pinene does not often occur in flowers, it is found more frequently in the oils from leaves, barks, and woods. It is the principal constituent of the distillate from the oleoresins of the several species of *Pinus*, which distillates are known in commerce as turpentine oils. French and Spanish turpentine oils contain as principal constituent *l*-*α*-pinene, whereas in American and Greek oils the dextrogyrate modification predominates. However, there are also American oils which are lævogyrate or nearly inactive.

The hydrocarbon *d*-*α*-pinene (the australene of Berthelot), besides occurring in American and Greek turpentine oil, has been found in Burmese turpentine oil, in the turpentine oil from *Pinus sylvestris*, in German, Polish and Swedish pine tar oils, in larch needle oil, in German and Swedish *Kiefernadelöl*, in *Zirbelkiefernadelöl*, in the oil from the leaves of *Juniperus phœnicea* and *Callitris glauca*, sandarac oil, in oil from the leaves of *Sequoia gigantea*, in cypress oil, in oil from the leaves and

¹⁾ Berl. Berichte 41 (1908), 866.

twigs of *Thuja plicata*, in the oil of *Alpinia malaccensis*, in the oils of galangal, star anise, ylang-ylang, nutmeg, camphor, apopin, *Persea*, in the oil from the fruits of *Pittosporum undulatum*, in Chios turpentine oil, in the oils of myrtle and checken, in the oils of *Melaleuca uncinata* and *M. nodosa*, in niaouli oil, in the oils of *Leptospermum Liversidgei*, *Eucalyptus botryoides* and *E. dextropinea*, in ajowan oil, coriander oil, carrot oil, cumin oil, asafetida oil, galbanum oil, fennel oil, water fennel oil (?), rosemary oil and in the basilicum oil from Réunion.

l-α-Pinene (the terebenthene of Berthelot) is contained in French turpentine oil, in the turpentine oil from *Picea excelsa*, in the Canada balsam oil from *Abies balsamea*, *A. amabilis*, in Oregon balsam oil from *Pseudotsuga mucronata*, in the needle oil from *Pinus Strobus*, in *Fichtennadelöl*, in the *Seesträndkielerknospenöl*, in the needle oil from *Pinus montana*, in the English *Kiefernnadelöl*, in hemlock needle oil, in the oils from the leaves and cones of *Abies alba*, in the needle oils from *Abies canadensis*, *Picea nigra*, *P. alba*, *Abies balsamea* and *A. sibirica*, in the oil of cubeb (?), the oils of *Asarum europæum* and *A. arifolium*, in the oils of Ceylon cinnamon and *Canella alba*, in the oil from *Umbellularia californica*, in the geranium oil from Réunion, in the oils of petitgrain, lemon, neroli, rue, frankincense, dacryodes resin and cajeput, in the oils from *Eucalyptus carnea*, *E. lævopinea* and *E. Wilkinsoniana*, in the oils from parsley, lavender, marjoran, American pennyroyal, spearmint (?), French peppermint, valerian, and kessoroot.

i-α-Pinene has been found in coriander oil, lemon oil, cumin oil, American peppermint oil, and oil of Levant wormseed.

α-Pinene has frequently been found in other oils, but its optical rotation has not been recorded. Thus in Venetian turpentine oil, in the pine tar oil from Finland, in the oil from the leaves and twigs of *Larix americana*, in Thuja oil, in juniper oil, in the oil from the resin of *Callitris verrucosa*, in matico oil, in pilea oil, in the oil from Canada snake-root, in boldo leaf oil, in cinnamon root oil, in the oil from Pichurim beans (?), in sassafras oil, the oil from sassafras leaves, in the oils from laurel leaves, massoy bark and Japanese pepper (?), in the oils of bergamot and lemon, in several elemi oils, in oil of myrrh, in the oil from the berries of *Schinus molle*, in the oils from the following species of *Eucalyptus*, viz., *acmenoides*, *allinis*, *aggre-*

*gata, albens, amygdalina, angophoroides, apiculata, Bæuerleni, bicolor, Bosistoana, Bridgesiana, Cambagei, camphora, capitellata, cinerea, cneorilolia, conica, cordata, corymbosa, crebra, dealbata, dives, dumosa, eugenoides, eximia, lastigiata, Fletcheri, fraxinoides, Globulus, goniocalyx, gracilis, hemilamprea, hemiphloia, intermedia, intertexta, lactea, longilolia, Luehmanniana, Macarthurii, macrorrhyncha, maculata, maculosa, Maidenii, melanophloia, melliodora, microcorys, microtheca, Morrisii, nova-anglica, odorata, oleosa, ovalilolia, o. var. lanceolata, paniculata, pendula, pilularis, polyanthema, polybractea, populilolia, propinqua, pulverulenta, punctata, p. var. didyma, quadrangulata, radiata, resinilera, Risdoni, robusta, Rossi, rostrata, r. var. borealis, rubida, saligna, siderophloia, sideroxyton, s. var. pallens, Smithii, squamosa, stricta, Stuartiana, tereticornis, tessellaris, trachyphloia, umbra, viminalis, viridis and Woolfsiana, in French parsley oil, rosemary oil, sage oil, in the oils of *Thymus capitatus* and *Satureja Thymbra*, in oil of spike, in golden rod oil, and in the oil of *Helichrysum Stachas*(?).*

In as much as a strongly active α -pinene yields little or no nitrosochloride, the formation of this substance is in reality indicative of *i*-pinene. Since in the above compilation of the occurrence of *d*- and *l*-pinene, the presence of pinene in more or less optically active fractions has been established by means of the nitrosochloride reaction, the presence of *i*-pinene should be assumed. The final determination of the presence of optically active pinene will, therefore, have to rest with the conversion of the optically active pinene into the corresponding optically active pinonic acid. Hence it becomes apparent how desirable it must be to revise the older investigations in the light of the new methods for the identification of pinene. (Comp. p. 297.)

α -Pinene is one of the few terpenes that can be obtained in a relatively pure state. It is obtained by heating the solid pinene nitrosochloride with aniline in alcoholic solution.¹⁾ The α -pinene thus obtained is always optically inactive and possesses the following physical constants:

B. p. 155 to 156°; d_{40}^0 0.858; n_{D21}^{20} 1.46553.²⁾

¹⁾ Wallach, Liebig's Annalen 252 (1889), 132; 258 (1890), 343.

²⁾ Wallach, Liebig's Annalen 258 (1890), 344.

An α -pinene regenerated from the nitrosochloride in the laboratory of Schimmel & Co. gave the following constants:

B. p. 154,5 to 155°; $d_{15} = 0,8634$; $n_D^{20} = 1,46644$.

The inactive form was also obtained by the decomposition of pinocampylxanthogenic acid ester.¹⁾ Gildemeister and Köhler²⁾ obtained, upon decomposition of *d*-pinocampylxanthogenic acid ester, active *d*- α -pinene, which, however, was rendered impure by the presence of another terpene.

The strict observation of certain conditions enabled Wallach³⁾ to prepare *l*- α -pinene from nopinolacetic acid.

Most oils containing pinene presumably contain mixtures of *d*- and *l*-pinene. Hence the direction of the rotation in all probability depends on the predominance of the one or the other modification. In order to prepare optically active modifications of α -pinene, it is best to start with pinene fractions possessing a high angle of rotation. It should be borne in mind, however, that this high angle of rotation may be produced by camphene. The fractions boiling below 160° are purified by fractional distillation over sodium until the boiling point and other properties correspond with those of *i*- α -pinene. The highest angles of rotation thus far observed are the following:

for *d*- α -pinene from Greek turpentine oil:

$[\alpha]_D^{20} + 48,4$ (b. p. 155 to 156°; $d_{15} = 0,8542$; $n_{D20} = 1,4634$).⁴⁾

$[\alpha]_D^{20} + 46,73$ (b. p. 156° at 760 mm; $d_{15} = 0,8642$; $n_{D20} = 1,46565$).⁴⁾

for *l*- α -pinene from the oil of *Eucalyptus laevopinea*:

$[\alpha]_{D110}^{20} - 48,63$ (b. p. 157°; $d_{15}^{19} = 0,8626$).⁴⁾

¹⁾ Tschugaeff, Journ. russ. phys. chem. Ges. 39 (1908), 1324; Chem. Zentralbl. 1908, I, 1179.

²⁾ Wallach-Festschrift. Göttingen 1909. p. 436.

³⁾ Liebig's Annalen 384 (1909), 1.

⁴⁾ Vèzes, Bull. Soc. chim. IV. 5 (1909), 932.

⁵⁾ Gildemeister and Köhler, Wallach-Festschrift. Göttingen 1909. p. 434; Report of Schimmel & Co. October 1900, 69.

⁶⁾ Smith, Journ. and Proceed. of the Royal Soc. of N. S. Wales 82 (1898), 195; Report of Schimmel & Co. April 1900, 24.

α -Pinene is a colorless, mobile liquid, which, like most terpenes, undergoes autoxidation upon standing by taking oxygen from the air and partly resinifies. It is readily converted into other terpenes. Thus by a higher temperature (250 to 270°) it is changed into dipentene, by moist hydrogen chloride into dipentene or its dihydrochloride, by means of alcoholic sulphuric acid into terpinolene and terpinene, presumably through the dipentene as an intermediate stage. Through the action of dry hydrogen halides α -pinene is changed to derivatives of camphor, a reaction that has become of great importance in the artificial production of camphor.

In the presence of water and oxygen, pinene yields pinol hydrate (sobrocol) $C_{10}H_{16}O_2$, which is at times found in old turpentine oils as a crystalline deposit. The active modifications of pinol hydrate melt at 150°, the inactive modification at 130.5 to 131°. When boiled with acids, pinol hydrate yields the oxide pinol, $C_{10}H_{16}O$, with its characteristic odor. In contact with dilute mineral acids, pinene is converted into terpin hydrate, $C_{10}H_{18}(OH)_2$, H_2O (m. p. 116 to 117°). As an intermediate product terpineol is formed, which likewise results upon the hydration of pinene with sulphuric and acetic acids.

When shaken with a 3 to 5 percent. sulphuric acid, pinene is acted upon but slowly.¹⁾ A suitable method for the hydration of pinene, according to Barbier and Grignard,²⁾ consists in acting on a solution of pinene in glacial acetic acid and acetic acid anhydride with a 50 percent. aqueous solution of benzene mono-sulphonic acid.

Oxidizing agents act on pinene in various ways. Whereas concentrated nitric acid produces so violent a reaction that ignition may take place, dilute nitric acid, like chromic acid mixture, produces — with pinol hydrate or pinol as intermediate products — in addition to lower fatty acids and other products, terephthalic acid, $C_8H_6O_4$, terebic acid, $C_8H_{10}O_4$, and terpenylic acid, $C_8H_{12}O_4$. Essentially different results are obtained with potassium permanganate. As shown by Wagner,³⁾ dilute per-

¹⁾ Wallach, *Nachr. K. Ges. Wiss. Göttingen* 1908, Meeting of February 8, p. 20.

²⁾ *Compt. rend.* 145 (1907), 1425; *Bull. Soc. chim.* IV, 3 (1908), 139; 5 (1909), 512, 519.

³⁾ *Berl. Berichte* 27 (1894), 2270; 28 (1896), 881.

manganate solution produces principally neutral oxidation products. When concentrated permanganate is used there results, in addition to other products, pinonic acid,¹⁾ $C_{10}H_{16}O_3$, a monobasic keto acid. Upon further oxidation this yields not only terebic acid, but also the "Abbau" products that are obtained upon oxidation of camphor derivatives.

According to the optical character of the initial material, a pinonic acid results that is optically active ($[\alpha]_D$ in chloroformic solution $+ or - 88$ to 90°) respectively inactive. The inactive modification melts at 103 to 105° , its oxime at 150° ; of the active modification the acids melt at $69,5$ to $70,5^\circ$, the oximes at 129° and the semicarbazones at 203 to 204° . Upon inversion with sulphuric acid methoethylheptanonolid results, the active modification of which melts at 46 to 47° , the inactive modification at 63 to 64° .

These compounds are suitable for the characterization of the several modifications of α -pinene. When pinene is acted upon by ozone, ozonides result which, upon cleavage with water, yield pinonic acid.²⁾

α -Pinene is an unsaturated hydrocarbon, with one double bond. Upon addition it is readily converted into derivatives of camphor. When dry hydrogen chloride or hydrogen bromide are passed into well dried and cooled pinene, halogenides of borneol result. Of these the chloride (the so-called "pinene chloride"), $C_{10}H_{16}HCl$, was designated "artificial camphor" because of its camphor-like odor. It melts at 125 to 127° ; the bromide, $C_{10}H_{16}HBr$, melts 90° . Both yield camphene when hydrohalogen is split off. True pinene monochlorhydrate was obtained by Wallach by the action of phosphorus pentachloride upon homonopinol. If bromine is allowed to act on pinene in dry solution, one molecule of bromine is readily decolorized and added. More bromine is added but slowly and is accompanied by the development of hydrogen bromide. When the addition product of one molecule of bromine to pinene is distilled with steam a dibromide melting at 169 to 170° is obtained.³⁾ A better

¹⁾ Tiemann and Semmler, Berl. Berichte **26** (1893), 1345; **29** (1896); 529, 3027; Baeyer, Berl. Berichte **29** (1896), 22, 326, 1907, 1923, 2775; Gildemeister and Köhler, Wallach-Festschrift. Göttingen 1909, p. 426.

²⁾ Harries and Neresheimer, Berl. Berichte **41** (1908), 38.

³⁾ Wallach, Liebig's Annalen **264** (1891), 8.

yield, however, is obtained by allowing hypobromous acid to act on pinene. This dibromide also appears to be a camphor derivative.¹⁾ When this dibromide is acted upon with aniline, hydrogen bromide is split off and cymene results. However, when acted upon with zinc dust in alcoholic solution, a new terpene, the tricyclene, m. p. 65 to 66 results.²⁾

The presence of α -pinene in a volatile oil can be ascertained by means of its nitrosochloride and its oxidation products. Provided the pinene reveals no high optical rotation, it is most readily identified by means of the nitrosochloride and by the conversion of the latter into its nitrolamine bases. For the preparation of the nitrosochloride, Wallach³⁾ has given the following directions: A mixture of 50 g. each of turpentine oil (immaterial whether laevo- or dextrogyrate), glacial acetic acid and ethyl nitrite⁴⁾ (preferably amyl nitrite⁵⁾) is well cooled in a freezing mixture and 15 cc. of crude (33 percent.) hydrochloric acid are gradually added. The nitrosochloride soon separates in a crystalline form, and is obtained in a fairly pure state when it is filtered off with a suction pump and well washed with alcohol. From the filtrate some more nitrosochloride separates on standing in the cold. It is profitable in regard to yield to work with small quantities, as only then can the low temperature be maintained which is necessary for the satisfactory conduct of the reaction; large quantities of pinol $C_{10}H_{18}O$ are formed as a by-product.

The nitrosochloride is a white crystalline powder, which is readily soluble in chloroform and may be again separated from this solution by methyl alcohol. The melting point of the recrystallized compound is 103°, though melting points as high as 115° have been observed. Like its derivatives it is optically inactive. According to observations by Baeyer⁶⁾ pinene nitrosochloride is a bisnitroso compound $(C_{10}H_{16}Cl)_2N_2O_2$, which in

¹⁾ Wagner and Ginzberg, Berl. Berichte 29 (1896), 890.

²⁾ Godlewsky and Wagner, Chem. Ztg. 21 (1897), 98.

³⁾ Liebig's Annalen 245 (1883), 251; 253 (1889), 251.

⁴⁾ This is easily obtained by allowing a mixture of 200 g. of concentrated sulphuric acid, 1.5 liters of water and 100 g. of alcohol to flow into a solution of 250 g. of sodium nitrite in 1 liter of water and 100 g. of alcohol. The ethyl nitrite which forms at once must be condensed in well cooled receivers.

⁵⁾ Report of Schimmel & Co. November 1906, 63.

⁶⁾ Berl. Berichte 28 (1895), 648.

etheral solution is changed by hydrochloric acid into hydrochlorocarvoxime.¹⁾ By splitting off hydrochloric acid with alcoholic potassa it is converted into nitrosopinene (m. p. 132°)²⁾ which has been recognized as an oxime.³⁾ Aromatic bases, such as aniline and toluidine split off nitrosylchloride, regenerating pinene with the formation of amidoazo-compounds. Quite different is the behavior of the nitrosochloride toward bases of the fatty series and those which possess their characteristics, as for instance, benzylamine and piperidine. With primary bases as well as with piperidine, nitrolamines result; the secondary bases, like diethylamine, however, produce a splitting-off of hydrochloric acid with the resulting formation of nitrosopinene.

As the nitrosochlorides of different terpenes show very similar melting points and besides decompose very readily, they are less suitable for characterization than the nitrolamines, which are very stable and crystallize readily; these have been prepared in large numbers, although the compounds produced by the reaction with benzylamine and piperidine are preferably used. For their preparation⁴⁾ the nitrosochloride is treated in excess with the base dissolved in alcohol and heated on a water bath; the nitrolamine formed is separated by the addition of water. The melting point of pinene nitrolpiperidine is 118 to 119°, that of the nitrolbenzylamine 122 to 123°.

It has already been pointed out that the yield of nitrosochloride diminishes with the increased optical rotation of the hydrocarbon material.⁵⁾ For the identification of pinene in highly active pinene fractions it is, therefore, more expedient to make use of the pinonic acid referred to above. 100 g. of pinene are shaken with 233 g. of potassium permanganate and 3 l. of water, the mixture being kept cool with ice. From the alkaline reaction mixture the excess of hydrocarbon is separated and

¹⁾ Berl. Berichte 29 (1896), 12.

²⁾ Wallach and Lorentz, Liebig's Annalen 265 (1891), 198.

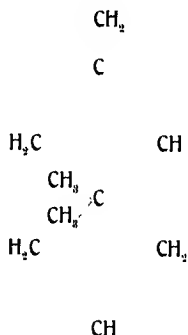
³⁾ Urban and Kremers, Am. Chem. Journ. 16 (1894), 404; Baeyer, Berl. Berichte 28 (1895), 646; Mead and Kremers, Am. Chem. Journ. 17 (1895), 607.

⁴⁾ Wallach, Liebig's Annalen 245 (1888), 253; 252 (1889), 130.

⁵⁾ Tilden, Journ. Chem. Soc. N. S. 15 (1877), 554; 86 (1904), 759; Kremers, Pharm. Rundsch. (New York) 13 (1895), 135. Gildemeister and Köhler, Wallach-Festschrift, Göttingen 1909, p. 433.

the neutral products are removed by shaking with ether. The pinonic acid is then precipitated with dilute sulphuric acid. For the identification of the pinene it suffices to convert the acid into its semicarbazone (m. p. 204°). If it is desired to establish the presence of optically active as well as inactive pinene, it is necessary to isolate the acid in its pure form. In most instances this can be accomplished by fractionation under diminished pressure (b. p. 168° at 12 mm.). The identification is then completed by determining the angle of rotation and by preparing the derivatives of the acid already described.

β-Pinene.



Side by side with α -pinene, nopinene or β -pinene occurs in the turpentine oils, also in pine tar oil, in Siberian *Fichtennadelöl*, and in the oils of lemon,¹⁾ coriander,²⁾ cumin,³⁾ hyssop⁴⁾ and nutmeg. Presumably it will be found in a large number of volatile oils. Synthetically it has been prepared by Wallach.⁵⁾ Starting with nopinone, this was condensed with bromacetic ester to

¹⁾ Gildemeister and Müller, *Wallach-Festschrift*, Göttingen 1909, p. 442.

²⁾ Walbaum and Müller, *Ibidem* 657; Report of Schimmel & Co. October 1909, 48.

³⁾ Report of Schimmel & Co. October 1909, 50.

⁴⁾ Gildemeister and Köhler, *Wallach-Festschrift*, Göttingen 1909, 417; Report of Schimmel & Co. April 1909, 58.

⁵⁾ Liebig's *Annalen* 363 (1908), 1.

nopinolacetic ester, which, when treated with acetic acid anhydride yielded β -pinene.

The following properties have been determined:

B. p. 164 to 166°; d_{18}^0 , 0.8650; α_D , $-19^\circ 29'$ (from hyssop oil); n_{D20}^0 , 1.47548.¹⁾

In connection with two preparations obtained at different times, Wallach²⁾ ascertained the following constants:

B. p. 163 to 164°; d_{22}^0 , 0.8675; α_D , $-22^\circ 5'$; n_{D22}^0 , 1.4749.

B. p. 162 to 163°; d_{22}^0 , 0.8660; α_D , $-22^\circ 20'$; n_{D22}^0 , 1.4724.³⁾

When acted on with glacial acetic acid-sulphuric acid mixture, β -pinene is in the main converted into terpinene.⁴⁾

β -Pinene yields no nitrosochloride. With hydrogen chloride it yields a mixture of dipentene dihydrochloride and bornylchloride. When acted upon by nitrous acid, nitroso- β -pinene results, which upon reduction is converted into amidoterebentene. This, in turn, when acted upon by nitrous acid, yields an alcohol, which when oxidized with chromic acid is converted into tetrahydrocuminic aldehyde (m. p. of the semicarbazone 201 to 203°) and cuminic acid (m. p. 115°).⁴⁾ From α -pinene it is readily distinguished by means of its oxidation products. When oxidized with permanganate, there results nopinic acid (m. p. 126 to 127°) which is readily isolated by its difficultly soluble sodium salt. As a by product there also results a glycol melting at 76 to 78°. For the identification of β -pinene, fraction 160 to 170° is oxidized according to Wallach's⁵⁾ directions for the preparation of nopinate of sodium. 300 g. of pinene are shaken, with the aid of a shaking machine, with a solution of 700 g. potassium permanganate in 9 l. water to which 150 g. of sodium hydroxide have been added. The reaction mixture becomes decidedly warm and the oxidation is completed in about 20 minutes. In the absence of alkali, about 12 hours are required before the per-

¹⁾ Report of Schimmel & Co. April 1908, 58.

²⁾ Liebig's Annalen **368** (1908), 1.

³⁾ Wallach, Liebig's Annalen **368** (1908), 1.

⁴⁾ Pesci and Bettelli, Gazz. chim. Ital. **16** (1886), 337; Wallach, Liebig's Annalen **346** (1906), 246.

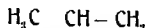
⁵⁾ Wallach, Liebig's Annalen **356** (1907), 228.

manganate is consumed. The excess of hydrocarbon is distilled off with steam, the mixture filtered to remove the oxide of manganese and the filtrate evaporated to about 3 l. while a current of carbon dioxide is passed into the evaporating liquid. Upon cooling, nopinate of sodium crystallizes out, which is separated with the aid of a forcefilter and purified by recrystallization.

The free nopinic acid from *l*- β -pinene has the following properties: m. p. 126°; d_4^{20} , 0.781; $\{a\}_D^{20}$, 15.64° (in ethereal solution).

For its further characterization nopinic acid can be oxidized to nopinone with either lead peroxide or permanganate in sulphuric acid solution. Nopinone is a ketone which has served as a steppingstone in the accomplishment of several interesting syntheses of terpenes and terpene derivatives. Of the derivatives of this ketone the following should be mentioned: the semicarbazone, m. p. 188°; the benzylidene compound, m. p. 106 to 107°; and the compound $C_{15}H_{26}OCl_2$ which results when HCl is passed into the alcoholic solution of the ketone and which melts at 148°.

Sabinene.



This hydrocarbon, which resembles *l*-pinene in some respects, has thus far been found in the oils of savin, Ceylon cardamom, marjoran and pilea. The following constants have been recorded:

B. p. 162 to 166°; d_{20}^{20} , 0.840; n_D^{20} , +63°; n_D , 1.466.¹⁾

B. p. 163 to 165°; d_{20}^{20} , 0.842; n_D^{20} , +67.5°; n_D , 1.4678.²⁾

¹⁾ Semmler, Berl. Berichte 33 (1900), 1464.

²⁾ Wallach, Liebig's Annalen 350 (1906), 163.

In connection with the fractionation of a larger amount of sabinene from savin oil, Schimmel & Co. determined the following constants:

20° boiling between 162 to 163°; d_{40}^0 , 0,8481; n_D^{20} , + 59° 30';

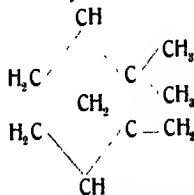
49° " " " 163 " 164°; " 0,8480; " + 63° 50';

31° " " " 164 " 165°; " 0,8482; " + 68° 54'.

Significant is the low specific gravity which distinguishes sabinene from other hydrocarbons with a similar boiling point.

When boiled with dilute sulphuric acid, sabinene is converted into terpinene; with hydrohalogens the corresponding terpinene dihalogenhydrates result; when shaken with dilute sulphuric acid in the cold, sabinene yields active terpinenol-4 and terpinene terpin (see terpineol). The oxidation with permanganate is analogous to that of β -pinene. The resulting sabinene glycol which melts at 54 and boils at 148 to 150° under 15 mm. pressure, has been used by Semmler for the identification of sabinene. Simpler, however, is the identification, according to Wallach, by means of the difficultly soluble sabinatate of sodium which results upon oxidation in the presence of free sodium hydroxide.¹⁾ The free sabinic acid melts at 57°. Like nopinic acid it can be oxidized to a ketone $C_{10}H_{16}O$, the sabinaketone, which likewise has served as a starting point for synthesis in the terpene group. The semicarbazone melts at 141 to 142°. When hydrogen chloride is passed into a methylalcoholic solution of sabinaketone, a mono-hydrochloride $C_{10}H_{15}OCl$, m. p. 77 to 78°, results, whereas in glacial acetic acid solution a compound $C_{11}H_{20}OCl_2$, m. p. 124°, is obtained. Sodium hypobromite oxidizes sabinaketone to thuja-dicarboxylic acid melting at 142 to 143°.

Camphene.



Although camphene is the only solid hydrocarbon $C_{10}H_{16}$ which occurs in Nature, its isolation in a crystalline state from

¹⁾ Wallach, Liebig's Annalen 359 (1908), 266.

volatile oils has been accomplished but rarely. In this form *l*-camphene has been isolated from the Siberian *Fichtennadelöl*; from the first fractions of Ceylon citronella oil Schimmel & Co. likewise obtained solid camphene. In the vegetable kingdom this hydrocarbon is found in both active modifications.

As *d*-camphene (the austreacamphene of Berthelot), it has been found in cypress oil, in Siberian *Fichtennadelöl*, in the oils of ginger, nutmeg, camphor, lemon, orange-petitgrain, sweet orange blossoms, of *Eucalyptus Globulus*, and spike.

As *l*-camphene (the tereacamphene of Berthelot),¹⁾ it has been found in the oil from the twigs of *Juniperus phœnicea* and in the oils of lemon, neroli (?), valerian, kesso, *Artemisia Herba-alba*, and of *Chrysanthemum sinense* var. *japonicum*.

In addition, camphene has been found in the oils of juniper berries, of the Douglas fir, citronella, Japanese cinnamon oil, bergamot, rosemary, and fennel.

Artificially camphene can be obtained in various ways, principally by splitting off hydrohalogen from bornylchloride or bornyl bromide (from pinene or borneol). Most conveniently, however, it is obtained upon dehydration of isoborneol with zinc chloride, though in this manner frequently mixtures of different hydrocarbons are obtained.

Camphene occurs as a white crummy-crystalline mass, with a faint camphor-like odor, that tends toward sublimation. Otherwise it is much more stable toward air and light than the other terpenes. In as much as it can be obtained in solid form and since by careful precipitation from its alcoholic solution with water it can be purified from liquid impurities, it is one of the few terpenes that have been prepared with a fair degree of purity. As its constants the following have been recorded:

for camphene from borneol-bornylchloride:

M. p. 48 to 49°; b. p. 160 to 161°²⁾; d_{40}^{20} , 0.850; $n_{D,40}^{20}$, 1.4555³⁾;

M. p. 53.5 to 54°; d_{40}^{20} , 0.83808; $n_{D,40}^{20}$, 1.45314⁴⁾;

¹⁾ The term tereacamphene is at times applied to any camphene prepared from pinenechlorhydrate.

²⁾ Wallach, Liebig's Annalen 230 (1885), 234.

³⁾ Wallach, *Ibidem* 245 (1888), 210.

⁴⁾ Brühl, Berl. Berichte 25 (1892), 164.

for camphene from pinene-bornylchloride:

M. p. 51 to 52°; b. p. 158,5 to 159,5°; d_{44}^{20} 0,84224; $n_{D_{55}}^{20}$ 1,45514°);

for camphene from isoborneol:

M. p. 50°; b. p. 159 to 160°; d_{44}^{20} 56° at 15 mm.

The corresponding values at 20° should be approximately d_{44}^{20} 0,870 and $n_{D_{55}}^{20}$ 1,470.

The angle of rotation of the camphene prepared artificially from pinene hydrochloride or bornyl chloride varies not only according to the angle of rotation of the initial material, but also according to the temperature — both height and duration — employed in the process. Thus Bouchardat and Lafont³⁾ obtained hydrocarbons, the $[\alpha]_D$, of which lay between $-80^{\circ}37'$ and $-30^{\circ}30'$ when they allowed *l*-pinene-bornylchloride ($[\alpha]_D$ $28^{\circ}30'$) to be acted upon by an alcoholic solution of potassium acetate at a temperature of from 150 to 170°.

In connection with a *d*-camphene obtained from borneol-bornylchloride, Kachler⁴⁾ observed $[\alpha]_{D_{55}}^{20} + 20^{\circ}$ (100,3 mm.).

The camphene molecule does not rearrange itself to isomeric forms as do other terpenes. While it is true that prolonged heating at a higher temperature, or treatment with dehydrating agents such as zinc chloride, phosphoric acid anhydride, or concentrated sulphuric acid changes it, the resulting decomposition products do not correspond to the formula $C_{10}H_{16}$.

As a terpene with one double bond, camphene yields addition products with halogen (m. p. of the dibromide 91 to 91,5°) and with hydrohalogen, but not with nitrosylchloride. However, compounds of camphene with the oxides of nitrogen have been obtained both directly and indirectly. Extensive investigations have been made concerning the relation between pinene hydrochloride, camphene hydrochloride, and the corresponding derivatives of borneol and isoborneol.

¹⁾ Brühl, Berl. Berichte 25 (1892), 162.

²⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 8.

³⁾ Compt. rend. 104 (1887), 694; Bull. Soc. chim. II. 47 (1887), 439.

⁴⁾ Liebig's Annalen 197 (1879), 97.

Camphene chlorhydrate is obtained by passing gaseous hydrochloric acid into an alcoholic solution of camphene. It melts at about 155°. References¹⁾ do not agree, the melting points recorded varying from 142 to 160°.

Oxidizing agents, such as permanganate, nitric acid, chromic acid mixture, and ozone, do not act in like manner on the hydrocarbon. The oxidation with permanganate would seem to indicate that artificial camphene is not a unit, but consists of a mixture of at least three hydrocarbons. Thus the oxidation of a camphene, obtained from *isoborneol*, with permanganate yields three different products: camphene glycol, $C_{10}H_{16}(OH)_2$, m. p. 200; camphene camphoric acid, $C_{10}H_{16}O_4$, m. p. 135.5 to 136; and eucelene, $C_{10}H_{16}$, m. p. 68, b. p. 152.8°. The further oxidation of camphene glycol yields camphenylic acid, $C_{10}H_{16}O_2$ (m. p. 171 to 172) and camphenilone, $C_9H_{14}O$ (m. p. 36 to 38). From natural camphene an isomeric camphene-camphoric acid (m. p. 142) appears to result which is not identical with the one mentioned above.²⁾ Nitric acid oxidizes camphene to the trihasic camphoylic acid (Marsh and Gardner), $C_{10}H_{11}O_6$ (Bredt's carboxylapocamphoric acid, m. p. 202). In addition minor amounts of the above-mentioned ketone $C_9H_{14}O$ result. Chromic acid mixture yields principally camphor with little camphoric acid and other products. Oxidation with ozone produces camphenilone.

However, none of these derivatives can be used to advantage for the characterization of camphene. With fairly pure fractions rich in camphene, the latter can be separated in the form of its chlorhydrate. It is better, however, to identify camphene by converting it into *isoborneol*. Should larger amounts of pinene be present, the identification of camphene by this method is difficult since terpinol as well as *isoborneol* is formed, and since the separation of the two can be attained but imperfectly.

¹⁾ Kachler and Spitzer, *Liebig's Annalen* 290 (1880), 343; Jünger and Klages, *Berl. Berichte* 29 (1896), 545; Reyckler, *ibidem* 32 (1899), 2302; Kondakow, *Journ. f. prakt. Chem.* II. 65 (1902), 201.

²⁾ Moycho and Zienkowski, *Liebig's Annalen* 340 (1905), 17, 40.

³⁾ Wallach, *Liebig's Annalen* 386 (1907), 84.

For the conversion of camphene into isoborneol the following method is used:¹⁾

100 parts of the camphene fraction are heated with 250 parts of glacial acetic acid and 10 parts of 50 percent. sulphuric acid for 2 to 3 hours to 50 to 60° with frequent shaking; the mixture which at first separates into two layers finally becomes homogeneous and has a slightly reddish color. When the reaction is ended, the acetate formed is separated by water, washed repeatedly, and then saponified by heating with a solution of 50 g. of potassium hydrate in 250 g. of alcohol. After removing the alcohol, the isoborneol is precipitated as a crumbly mass by the addition of water and is purified by recrystallization from petroleum ether. The melting point of isoborneol is about 212°; the determination must, however, be made in a sealed capillary tube on account of its great tendency to sublime. For the further characterization of the isoborneol, its bromal compound, m. p. 71 to 72° may be used.

It should be remembered, however, that this isoborneol always contains some borneol. The phenylurethanes of both alcohols melt at 138 to 139°.

Recent observations appear to render it probable that camphene occurs in several modifications which differ from each other not only by their physical constants, but also by their oxidation products. As to their constitution, however, no details are as yet known. Thus Wallach²⁾ isolated from a Siberian pine needle oil a camphene with the following properties:

M. p. 39°; b. p. 160 to 161°; $d_{40} = 0.8555$; $[a]_D = -84.9^\circ$; $n_{D,40} = 1.46207$; mol. refr. 43.71; calculated for $C_{10}H_{16}$ 43.53.

Upon oxidation of this camphene with permanganate there resulted an acid, isomeric with camphene-camphoric acid, that melted at 142°. Its chlorhydrate melted at 51°. The same camphene has likewise been found in citronella oil.

By acting on bornylamine with sodium nitrite, Wallach³⁾ obtained a camphene (m. p. 50°; b. p. 160 to 161°), which was characterized by a remarkably strong optical rotation ($[a]_D + 103.89^\circ$).

¹⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 1. -- In addition to isoborneol some borneol is formed. Aschan, Berl. Berichte 40 (1907), 4923.

²⁾ Liebig's Annalen 357 (1907), 79.

³⁾ Ibidem 84.

Fenchene.

A positive proof for the occurrence of fenchene in volatile oils has not yet been brought. The inference of its presence in terpene fractions boiling about 160° has been drawn from the formation of fenchyl alcohol. Thus Bouchardat and Tardy¹⁾ obtained from an oil of *Eucalyptus Globulus* a terpene which, when heated with benzoic acid, yielded fenchyl alcohol. Upon heating French turpentine oil with sulphuric acid ($\frac{1}{10}$ of its weight), and the reaction product with an excess of alcoholic potassa in an autoclave to 150°, these same authors obtained a readily soluble potassium salt which, upon addition of water, broke up into potassium acid sulphate and *d*-fenchylalcohol.²⁾ When repeating this experiment, Schimmel & Co., however, could not find this alcohol.³⁾ In as much as it is not impossible that this terpene may occur as such in nature, mention of these observations should here be made.

Artificially fenchene has been obtained by the dehydration of fenchyl alcohol, also by splitting off hydrogenchloride from fenchyl chloride.⁴⁾ Synthetically it has also been obtained from nopinone, an "Abbau" product of β -pinene.⁵⁾ Upon diazotation of fenchylamine with nitrous acid, Wallach⁶⁾ obtained, in the main, a fenchene which boiled at 156 to 157°; $d_{15} 0.869$; $n_D^{20} 1.4729$.

The isomeric complexities are even greater in the case of the fenchenes than in that of the camphenes. Possibly not one of the fenchenes thus far obtained represents a chemical unit. Even when the method of preparation employed was the same, differences in the constants, more particularly in the angle of rotation, were observed. In addition to semicyclic fenchenes, there appear to be fenchenes with double linkage in the cycle, the boiling point of which is appreciably lower. Fenchene has thus far been obtained only in the liquid state. Its odor

¹⁾ Compt. rend. 120 (1895), 1418.

²⁾ Compt. rend. 125 (1897), 113.

³⁾ Report of Schimmel & Co. April 1904, 53.

⁴⁾ Wallach, Liebig's Annalen 263 (1891), 149.

⁵⁾ Wallach, *Ibidem* 357 (1907), 53; 368 (1908), 3.

⁶⁾ *Ibidem* 362 (1908), 180.

reminds of that of camphene. The following constants have been determined:

B. p. 154 to 155°; d_{15}^4 , 0,8660; n_{D15}^4 , 1,4693.

B. p. 155 to 156°; d_{15}^4 , 0,8670; n_{D15}^4 , 1,47047; $[\alpha]_D^{21}$, + 21°.)

Repeated determinations in the laboratory of Schimmel & Co. revealed the following constants:

B. p. 154 to 156° (765 mm.); d_{15}^4 , 0,8660 to 0,8665; n_{D15}^4 , 1,46733 to 1,46832.

From the *l*-fenchene ($[\alpha]_D^{20}$ — 32° 12') mentioned above, Wallach³⁾ prepared a dextrogyrate dibromide which melted at 87 to 88° and which revealed a specific rotation of + 42,83°. A dibromide prepared from *d*-fenchene (the fenchene being obtained from *l*-fenchone from thuja oil) likewise melted at 87 to 88°. A mixture of equal parts of both bromides, upon recrystallization, showed the melting point 62°.)

No other characteristic halogen or hydrohalogen or nitrosyl-chloride addition products are obtainable that might be used for the identification of fenchene. However, in like manner as camphene, fenchene can be hydrated to $C_{10}H_{18}O$ by means of the glacial acetic acid and sulphuric acid mixture. The alcohol thus obtained is *isofenchyl* alcohol (m. p. 61,5 to 62°) which yields with phenylisocyanate a phenylurethane melting at 106 to 107°.)

From the semicyclic fenchenes there result, upon oxidation with potassium permanganate, hydroxyfenchene acids which are characterized by difficultly soluble sodium salts.

ISOFENCHENE. The *isofenchene* obtained by Bertram and Helle⁶⁾ from *isofenchyl* alcohol was recognized by Wallach⁷⁾ as *D-d*-fenchene.

¹⁾ Wallach, Liebig's Annalen 300 (1898), 313.

²⁾ Wallach, *Ibidem* 302 (1898), 376.

³⁾ *Ibidem* 362 (1908), 182.

⁴⁾ *Ibidem* 199.

⁵⁾ Bertram and Helle, Journ. f. prakt. Chem. II. 61 (1900), 293; Report of Schimmel & Co. October 1898, 48; April 1900, 56.

⁶⁾ Journ. f. prakt. Chem. II. 61 (1900), 303.

⁷⁾ Liebig's Annalen 362 (1908), 193.

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⁴⁾ Wallach, Liebig's Annalen 263 (1891), 149.

⁵⁾ Wallach, *Ibidem* 357 (1907), 53; 368 (1908), 3.

⁶⁾ *Ibidem* 362 (1908), 180.

hydrocarbon has an agreeable lemon-like odor. The physical constants are approximately expressed by the following figures:

B. p. 175 to 176°; d_{15}^4 , 0,850; n_{D20}^4 , 1,475.

For *l*-limonene from the leaves of *Abies alba* Wallach found:

B. p. 175 to 176°; d_{20}^4 , 0,846; n_{D20}^4 , 1,47459.¹⁾

The angle of rotation is high, but varies with the method of preparation. The highest deviation recorded was observed in the laboratory of Schimmel & Co. in connection with a *d*-limonene obtained from caraway oil by fractionation in vacuum, viz., $[\alpha]_D + 123^\circ 40'$. A synthetic limonene prepared by Godlewski and Roshanowitsch²⁾ gave $[\alpha]_D + 125^\circ 36'$. For *l*-limonene from pine needle oil, Wallach³⁾ records $[\alpha]_D - 105'$ (in alcoholic or chloroformic solution). In connection with *l*-limonene from pine cone oil, the following constants were observed in the laboratory of Schimmel & Co.

B. p. 176,5°; d_{15}^4 , 0,8472; $\alpha_D - 101^\circ 10'$, $[\alpha]_D - 119,41^\circ$; n_{D20}^4 , 1,47303.

Chemically both limonenes are alike, yielding the same derivatives which differ only in the direction in which they deviate polarized light. When *d*- and *l*-limonene are mixed, dipentene results. This also results when the active limonenes are heated to a higher temperature or when they are acted upon with acids. In the cold, acids frequently cause the hydration of limonene to terpineol and terpin hydrate. At elevated temperatures, however, acids dehydrate these same hydration-products with the reformation of hydrocarbons. Concentrated sulphuric acid changes limonene to cymene. When perfectly dry, limonene absorbs one molecule of hydrohalogen with the formation of limonene monochlorhydrate which, when treated with sodium acetate, yields active α -terpineol.⁴⁾ A second molecule of hydrohalogen is added only in the presence of moisture when a derivative of dipentene (see p. 313) is formed.

¹⁾ Liebig's Annalen 246 (1888), 222.

²⁾ Journ. russ. phys. chem. Ges. 31 (1899), 209. According to Chem. Zentralbl. 1899, I. 1241.

³⁾ Liebig's Annalen 246 (1888), 222; Wallach and Conrady, *Ibidem* 252 (1889), 145.

⁴⁾ Semmler, Berl. Berichte 28 (1895), 2190; Wallach, Liebig's Annalen 359 (1906), 154.

Limonene adds 4 atoms of bromine yielding an optically active limonene tetrabromide that melts at 104 to 105° (see below). Upon addition of nitrosyl chloride, each limonene yields two (α - and β -) nitrosochlorides¹⁾ which are physical isomers. These are prepared like pinene nitrosochloride and because of their different solubility in chloroform can be separated by means of this solvent. Chemically these nitrosochlorides behave alike. Upon withdrawal of hydrogen chloride with alcoholic potassa, they are converted into carboxime melting at 72°. When treated with organic bases two series of nitrolamins²⁾ result. Of these the α -nitrol piperidine base melts at 94°, the β -compound at 110°; the α -nitrol anilide base at 112°, the β -compound at 153°; the α -nitrol benzylamine base at 93°. The limonene monochlorhydrate mentioned above also yields a nitrosate.

With dilute permanganate solution limonene is oxidized to the saturated tetratomic alcohol limonetrine (m. p. 191,5 to 192°).³⁾ The other oxidation products of limonene afford little that is characteristic.

Limonene is most readily identified by means of its tetrabromide, prepared according to Wallach's directions.⁴⁾ The fraction is purified as much as possible and diluted with about four times its volume of glacial acetic acid. Bromine is added drop by drop to the well cooled solution as long as it is taken up with decoloration. The crystals separating after standing for some time are collected and recrystallized from acetic ether. As a rule they are distinguished from those of dipentene tetrabromide by having smooth surfaces, and by being soft and flexible.⁵⁾ The melting point of the pure tetrabromide is about 104,5°, the specific rotation of the chloroform solution is +73,27 and -73,45° respectively.

In connection with the preparation of the tetrabromide, it should be noted that reagents absolutely free from water need not and should not be used. These are apt to give rise to the formation of a non-crystallizable tetrabromide. Nevertheless the crystalline product is to be regarded as the normal bromide.⁶⁾

¹⁾ Wallach, *Liebig's Annalen* 252 (1889), 109.

²⁾ Wallach, *Ibidem* 270 (1892), 172.

³⁾ Wagner, *Berl. Berichte* 23 (1890), 2315.

⁴⁾ *Liebig's Annalen* 289 (1887), 3.

⁵⁾ Wallach, *Liebig's Annalen* 227 (1885), 279.

⁶⁾ Wallach, *Ibidem* 264 (1891), 14.

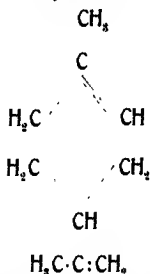
Wallach also advises not to use alcohol or ether as diluent since they give rise to the formation of liquid by-products. Like disturbing factors are encountered when the terpene fractions used are not sufficiently uniform in composition.

Minor modifications in the method of preparation have been recommended by various investigators. Baeyer and Villiger¹⁾ employ as diluent a mixture of 1 vol. of amylalcohol and 2 vol. ether, cool the mixture and add bromine drop by drop. In the proportion in which the ether evaporates, the tetrabromide is said to crystallize out.

Power and Kleber²⁾ add the fraction to be tested for limonene drop by drop to a cooled mixture of glacial acetic acid and bromine until only a slight excess of bromine remains. The solution is then decolorized with an aqueous solution of sulphur dioxide and the bromide precipitated with water. Their object is to prevent the formation of hydrogen bromide and of non-crystalline bromides of isomeric terpenes.

Finally, a combination of both methods has been suggested by Godlewsky.³⁾ He suggests that a solution of the terpene in a mixture of equal parts of amylalcohol and ether be added drop by drop to an ethereal solution of bromine which is kept cold by ice water during the course of the reaction.

Dipentene.



The optically inactive form of limonene, the dipentene, has been found frequently in nature, though not as commonly as

¹⁾ Berl. Berichte 27 (1894), 448.

²⁾ Pharm. Rundschau (New York) 12 (1894), 160; Arch. der Pharm. 222 (1894), 646.

³⁾ Chem. Ztg. 22 (1898), 827.

limonene. It must also be born in mind that the dipentene identified may have been formed from pinene or limonene during the process of fractionating the oil. Dipentene has been found in the following oils: In the oils from the turpentines of different species of *Pinus*, in pine tar oils, in the needle oil from *Picea excelsa*, in Swedish turpentine oil, in Siberian pine needle oil, in the needle oil from *Callitris glauca*, in the oils of palmarosa, lemongrass, citronella, gingergrass, cardamom, pepper, cubeb, nutmeg, boldo leaves, kuromoji, campher, cinnamon root, massoy-bark, apopin, bergamot, lime leaves, neroli, wartara, buchu, frankincense, myrrh, myrtle, ajowan, coriander, cumin, and fennel, also in the oils of *Satureja Thymbra*, *Thymus capitatus*, in American pennyroyal oil, in kessoroot oil and in goldenrod oil.

Aside from its formation from equal parts of *d*- and *l*-limonene, it is obtained synthetically by polymerization of the unsaturated aliphatic hydrocarbon isoprene, C_5H_8 ; also, together with terpinene, upon dehydration of the aliphatic alcohols linalool and geraniol. Furthermore, it results upon isomerization of other hydrocarbons $C_{10}H_{16}$, e. g. pinene, limonene, phellandrene; also by inducing the proper changes in related oxygenated compounds, such as cineol, terpineol, and terpinhydrate. Dipentene, together with cineol and limonene, was also obtained by the action of nitrous acid on fenchylamine.

A relatively pure dipentene can be obtained by the dry distillation of caoutchouc. After the removal of the isoprene, fraction 172 to 178° is carefully and repeatedly fractionated over sodium. The presence of any cineol, which has a like boiling point, can be ascertained by a corresponding increase in the specific gravity. A less pure preparation can be obtained from dipentene dihydrochloride by splitting off hydrogen chloride with aniline or sodium acetate in glacial acetic acid;¹⁾ also by the dehydration of crystalline terpineol by means of potassium acid sulphate.²⁾

Physically, dipentene differs from limonene only by its optical inactivity. The boiling point of pure dipentene appears to be the

¹⁾ Wallach, Liebig's Annalen 220 (1887), 3; 245 (1888), 196. Comp. also Tilden and Williamson, Journ. chem. Soc. 68 (1893), 294.

²⁾ Wallach, Liebig's Annalen 225 (1893), 109.

same as that of limonene. However, when in research for dipentene, it is necessary to take into consideration fractions that boil somewhat higher than the corresponding limonene fractions.¹⁾ Specific gravity and index of refraction agree fully with those determined for limonene. For dipentene from caoutchouc the following data were ascertained in the laboratory of Schimmel & Co.:

B. p. 175 to 176°; d_{20} 0.844; n_{D20} 1.47194.

Dipentene is relatively stable. When heated it is not converted into isomeric hydrocarbons $C_{10}H_{16}$, but polymerizes. However, when heated with alcoholic sulphuric acid, it is changed to terpinene. Its derivatives are inactive and can be obtained from dipentene as well as by the union of equivalent amounts of the corresponding derivatives of limonene. The dipentene derivatives reveal minor differences from the corresponding limonene derivatives, notably in their melting points. Toward hydrohalogen, bromine and nitrosylchloride dipentene behaves like the active limonenes. The solid addition products that result upon the addition of two molecules of hydrohalogen, exist in two modifications, viz., the *cis*- and *trans*-forms.²⁾ Of these the one with the lower melting point and the greatest solubility is designated the *cis*-form. The higher melting *trans*-form is the more stable and always results when the reaction mixture is allowed to become warm. In the cold, both forms usually result simultaneously. In as much as the *trans*-form results in most cases, the following data pertain to this modification. The dichlor-, dibrom- and diiod-hydrates of dipentene result when hydrohalogen is passed to saturation into an ethereal or glacial acetic acid solution of either limonene or dipentene. Upon evaporation of the solvent, or upon the addition of water thereto the compounds separate in the form of an oil which soon crystallizes. Since terpinene yields analogous compounds, and since mixtures frequently cause very appreciable melting point depressions, these compounds may prevent each other from crystallizing. However, a separation of the dihydrohalogen addition products of dipentene

¹⁾ Wallach, Liebig's Annalen 286 (1895), 138; Berl. Berichte 40 (1907), 600.

²⁾ Baeyer, Berl. Berichte 26 (1893), 2861.

and terpinene may be obtained by taking into consideration their difference in stability toward dilute alkali.¹⁾

Dipentene dichlorhydrate melts at 50° and can be crystallized from its alcoholic solution by the careful addition of water; the dibromhydrate forms rhombic, shiny plates that melt at 64°; the diiodhydrate crystallizes in various forms and melts between 77 to 81°. From all of these, dipentene can be regenerated upon the withdrawal of hydrohalogen. When shaken with dilute alkali, they yield α -terpineol and terpinhydrate.

As in the case of limonene, so the nitrosochloride of dipentene exists in two physically isomeric forms (α and β), which are more soluble than their active components. When treated with alcoholic potassa, they lose hydrogen chloride and yield inactive carboxime m. p. 93°. When treated with organic bases, the nitrosochlorides yield two nitrolamines in each case; of these the nitrolamine bases melt at 154 and 152° respectively, the nitrol aniline bases at 125 and 149°, and the particularly characteristic α -nitrolbenzylamine base at 110°. A dipentene nitrosate, also a nitrosate of the dipentene monoehlorhydrate are known.²⁾

For the identification of dipentene the preparation of its tetrabromide³⁾ is commonly resorted to. It is prepared, like the limonene tetrabromide, from dipentene, or when concentrated solutions of equal parts of *d*- and *l*-limonene tetrabromide are mixed.⁴⁾ The crystals differ from those of limonene tetrabromide by their appearance, the dipentene tetrabromide revealing peculiar striations in the vertical zone. They are also very fragile. Dipentene tetrabromide also differs from the limonene tetrabromides by its lesser solubility and its higher melting point, viz., 124 to 125°. For its identification the above-mentioned nitrosochloride and the corresponding nitrolbenzylamine base can be used, also the carboxime obtained from the nitrosochloride and finally the dichlorhydrate described above.

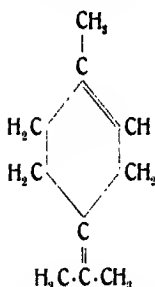
In the case of mixtures of limonene and dipentene, which may not occur infrequently, it should be remembered that, as a rule, the dipentene compounds separate first.

¹⁾ Wallach, Liebig's Annalen 350 (1906), 160.

²⁾ Wallach, Liebig's Annalen 245 (1888), 258.

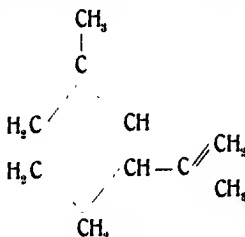
³⁾ Wallach, Liebig's Annalen 227 (1885), 278.

⁴⁾ Wallach, *ibidem* 246 (1888), 226.

Terpinolene.

Thus far this terpene has been obtained by synthetical means only, although Clover¹⁾ claims to have found it in a Manila elemi oil, observing at the same time a gradual inversion into dipentene. Recently its presence in coriander oil has likewise been rendered probable.²⁾

The boiling point of terpinolene is in the neighborhood of about 185 to 187°. As characteristic derivatives, the tetrabromide melting at 116° and the dibromide melting at 69 to 70° should be mentioned. The addition of hydrohalogen yields the corresponding dipentene derivatives. Upon oxidation with potassium permanganate, terpinolene erythritol, $C_{10}H_{18}(OH)_2 \cdot H_2O$, melting at 148 to 150°, results.

Sylvestrene (i-Sylvestrene = Carvestrene).

Sylvestrene is one of the less common natural terpenes. Thus far it has been found, always in the dextrogyrate modi-

¹⁾ Philippine Journ. of Sc. 2 (1907), A. 17.

²⁾ Report of Schimmel & Co. October 1900, 48.

fication, in the oils of the *Pinaceæ*: in the pine tar oils of Sweden and Finland, in the turpentine oils of Finland, Russia, and Sweden, in the needle oil of *Pinus sylvestris* of Germany, Sweden, and England, in the needle oil of *Pinus montana*, and in cypress oil. The statement by More¹⁾ that *l*-sylvestrene occurs in the oil from the resin of *Dacryodes hexandra*, still needs verification.

It can be obtained in a relatively pure state by preparing the dichlorhydrate from fractions rich in sylvestrene and by subsequent regeneration by boiling the hydrochloride either with aniline²⁾ or with sodium acetate and glacial acetic acid.³⁾ The hydrocarbon thus obtained closely resembles limonene in its physical and chemical properties. Like the limonene, it has a pleasant odor resembling that of limonene. Specific gravity and boiling point agree well with the corresponding constants of limonene.

Atterberg, the discoverer of sylvestrene, found the following constants:

B. p. 173 to 175 ; d_{16} 0,8612; $[\alpha]_{D16} + 19,5^{\circ}$.⁴⁾

Wallach records the following:

B. p. 176 to 177 ; d_{16} 0,851; n_D 1,47799.⁵⁾

B. p. 175 to 176°; d_{20} 0,848; $[\alpha]_D + 66,32^{\circ}$ (in chloroformic solution); n_D 1,47573.⁶⁾

When heated to 250°, sylvestrene is polymerized, but not isomerized, neither is the latter change brought about by alcoholic sulphuric acid. Hence this hydrocarbon is one of the most stable of the terpene group. Like limonene, so sylvestrene contains two double bonds that can be satisfied either entirely or in part by hydrohalogen, bromine, or nitrosyl chloride. Peculiar, however, is the dichlorhydrate which, unlike the inactive dipenten dihydrochloride, is optically active (dextrogyrate) and, hence,

¹⁾ Journ. chem. Soc. 75 (1899), 718.

²⁾ Wallach, Liebig's Annalen 280 (1885), 243.

³⁾ Wallach, Liebig's Annalen 289 (1887), 25; 245 (1888), 107.

⁴⁾ Berl. Berichte 10 (1877), 1206.

⁵⁾ Liebig's Annalen 245 (1888), 198.

⁶⁾ Liebig's Annalen 252 (1889), 149.

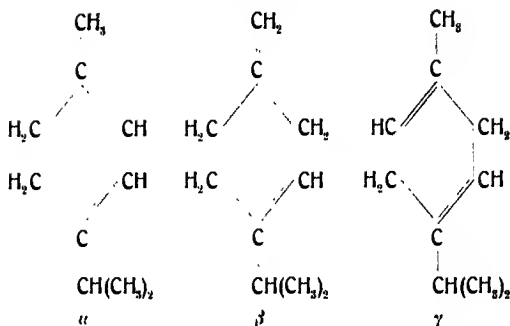
which active sylvestrene can be regenerated upon splitting off hydrohalogen. The tetrabromide, prepared like that of the limonene, melts at 135 to 136°; however, it is difficult to obtain it in solid state when, as is mostly the case, other terpenes are present in the fraction. With amyl nitrite and hydrochloric acid, pure sylvestrene yields a nitrosochloride melting at 106 to 107°, and this with benzylamine an nitrolamine base that melts at 71 to 72°.

For the separation of sylvestrene from mixtures, as well as for its identification, the chlorhydrate is best suited. This compound, which can be separated in crystalline form at considerably reduced temperatures only, is prepared in the following manner. The fraction in question is diluted with an equal volume of ether and saturated with hydrogen chloride gas. After standing for about two days, the ether is distilled off and the residue induced to crystallize by considerably reducing its temperature. With the aid of porous plates the crystalline magma is freed from oily admixture and recrystallized from an equal weight of alcohol. The hydrochloride thus partly purified, is freed from the corresponding dipentene compound by fractional crystallization from ether, in which the latter is more difficultly soluble. The purified dihydrochloride melts at 72°. ¹⁾ It should be remembered that, in the presence of dipentene or of such terpenes that yield dipentene dihydrochloride when acted upon by hydrogen chloride, mixtures of chlorhydrates result, the melting point of which is lowered with the increasing content of dipentene dihydrochloride. The dibromohydrate of sylvestrene melts at 72°, the diiodohydrate at 66 to 67°. By treating these dihalogen hydrates with dilute potassium hydroxide, sylveterpin, $C_{10}H_{18}(OH)_2$, m. p. 135 to 136°, also sylveterpineol, $C_{10}H_{17}OH$, b. p. 210 to 214°, ²⁾ result. These compounds correspond with those obtained in like manner from dipentene dihydrochloride.

If to a solution of a few drops of sylvestrene in acetic acid anhydride a drop of concentrated sulphuric acid be added, a beautiful blue color is produced. This reaction succeeds only then when the fraction to be tested is rich in sylvestrene.

¹⁾ Wallach, Liebig's Annalen 290 (1885), 241; 299 (1887), 25.

²⁾ Wallach, Liebig's Annalen 357 (1907), 72.

Terpinene.

Until very recently our knowledge of the occurrence of terpinene was very limited. Besides the dihalogen addition product, also yielded by other terpenes, the addition product of nitrous acid was the only characteristic derivative. The designation terpinene heretofore applied to a hydrocarbon which yielded, with nitrous acid, a nitrosite melting at 155°. The artificially prepared hydrocarbon is a mixture of two isomers, designated α- and γ-terpinene by Wallach, the composition of which varies with the method of preparation.

The hydrocarbon was first found by Weber¹⁾ in the oil of the long Ceylon cardamom. With the aid of the nitrosite m. p. 155°, its presence was likewise established in the oil of Levant wormseed, in Manila elemi oil, in the oil of dill herb, and in marjoran oil. The presence of both constituents, found by Wallach in what is designated artificial terpinene, in volatile oils was first revealed by the investigations in the laboratory of Schimmel & Co.²⁾ Thus α-terpinene was found in coriander oil, γ-terpinene in ajowan oil, lemon oil, and coriander oil.

Artificially, terpinene is obtained by the action of acids upon such hydrocarbons as pinene, dipentene, and phellandrene; or upon such oxygenated compounds as linalool, geraniol, terpi-

¹⁾ Liebig's Annalen 288 (1887), 107.

²⁾ Gildemeister and Müller, *Wallach-Festschrift*, Göttingen 1909, p. 443.

neol, terpinenol, terpinene terpin, terpinhydrate, dihydrocarveol, and cineol; further by splitting off hydrohalogen from the terpinene halogenides; and by special decomposition of carvylamine, carvenone, and methyl-dichlormethyl-ketodihydrobenzene. Especially adapted to the preparation of products rich in α -terpinene are the syntheses of Semmler¹⁾ and Auwers.²⁾ Pure products, however, are not obtained; hence the constants are but approximations. For a terpinene obtained by the action of methylmagnesium iodide on sabinaketone and purified by repeated distillation over sodium, Wallach³⁾ records the following constants:

B. p. 174 to 179°; d_{20}^4 0.842; n_D 1.4719;

and for a preparation regenerated from its hydrochloride by heating with aniline:⁴⁾

B. p. 179 to 181°; d_{20}^4 0.846; n_D 1.4789.

In connection with a fraction from coriander oil consisting of α - and γ -terpinene, Schimmel & Co. observed the following constants:

B. p. 177 to 178°; d_{16}^4 0.8485; α_D +0°32'; $n_{D,20}^4$ 1.47650.

Terpinene bears a great resemblance to dipentene. When acted upon by the hydrohalogens, terpinene halogenhydrides result which might easily be confounded with those of dipentene. Both *cis*- and *trans*-modifications exist. However, the latter only are concerned so far as identification is meant, for the former are liquid.

Terpinene dihydrochloride melts at 51 to 52°, the dihydrobromide at 58 to 59°, the dihydroiodide at 76°. From the corresponding isomeric dipentene compounds they can be distinguished by the decided depression of the melting point of their respective mixtures. When the hydrochloride is boiled with bases, a mixture of several hydrocarbons results. When shaken with dilute potassium hydroxide solution, terpinene terpin (m. p. 137

¹⁾ Ber. Berichte 41 (1908), 4474; 42 (1909), 522.

²⁾ *Ibidem* 42 (1909), 2424.

³⁾ Liebig's Annalen 362 (1908), 301.

⁴⁾ Liebig's Annalen 350 (1906), 149.

to 138°), terpinenol-4, and γ -terpinenol result, also *cis*- and *trans*-terpin.

The addition of bromine to terpinene yields liquid compounds only. Neither could a nitrosochloride be obtained. Upon addition of nitrous acid, terpinene nitrosite melting at 155° results, which yields nitrolamines when acted upon with piperidine and nitrolamines. The nitrolpiperidine base melts at 153 to 154°, the nitrolbenzylamine base at 137°. Careful reduction of the terpinene nitrosite and its nitrolamines with zinc dust and glacial acetic acid yields carvone. The use of more energetic reducing agents, such as sodium and alcohol, is apt to yield tetrahydrocarvone and tetrahydrocarvylamine. According to Wallach the nitrosite is a derivative of α -terpinene, which, upon oxidation with permanganate yields *i*- α , α' -dihydroxy- α -methyl- α' -isopropyladipic acid melting at 188 to 189°, and the lactone of which melts at 72 to 73°. Further oxidation of this acid yields dimethylacetylacetone, the semicarbazide of which melts at 201 to 202°, and the dioxime at 137°.

When oxidized in like manner, γ -terpinene yields the erythritol $C_{10}H_{16}(OH)_4$, m. p. 237°. When acted upon by dilute sulphuric acid this is converted into carvacrol and thymol.

For the identification of terpinene in volatile oils, fraction 175 to 185° is examined. Some clue may be had from the formation of terpinene dihydrochloride, m. p. 52°, by passing hydrogen chloride gas into a glacial acetic acid solution of the hydrocarbon. Thujene and sabinene, also terpinenol and terpinene terpin, which also yield the same chloride, boil at either higher or lower temperatures. Particularly suited for identification is the terpinene nitrosite, which is prepared in the following manner: To 3 ccm. of the hydrocarbon fraction to be examined, in a narrow test tube, 1½ ccm. glacial acetic acid and 4½ ccm. of water are added. To the well cooled mixture a concentrated aqueous solution of 1.5 g. of sodium nitrite is added, a small portion at a time, causing the hydrocarbon to assume a green color. When the nitrous acid has been absorbed completely, a reddish-yellow color results. In order to avoid supersaturation, the reaction mixture is inoculated with a crystal of pure nitrosite. The crystals which separate in the course of time are washed

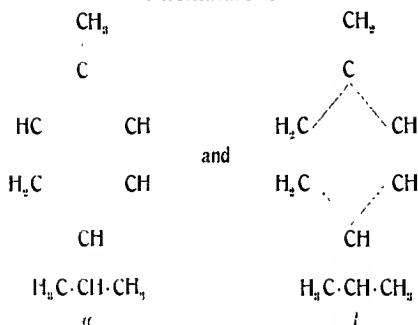
with water and petroleum ether and crystallized from alcohol (m. p. 155°).

The presence of one or the other modifications of terpinene can be established positively only by oxidation with permanganate. Wallach¹⁾ proceeds in the following manner: A mixture of 7 g. of the hydrocarbon, 33 g. of potassium permanganate, 14 g. potassium hydroxide, 400 g. ice and 400 ccn. water, contained in a copper flask, is shaken with a shaking machine for an hour. The excess of hydrocarbon is distilled off, the oxide of manganese separated by filtration, and the filtrate saturated with carbon dioxide while it is being evaporated to dryness. The residue is extracted with alcohol, the alcoholic filtrate evaporated to dryness, this residue dissolved with a small amount of hot water and the solution set aside for crystallization. The magna of crystals is separated, washed with a little cold water, dried on porous plate and recrystallized from 15 to 20 times its weight of 25 p. c. alcohol. The melting point of this oxidation product, the erythritol mentioned above, lies at 235 to 236°, or if heated rapidly at 237 to 238°. It is sparingly soluble in ether, ligroin, ethylacetate, or chloroform; not readily in cold alcohol or water, but more readily in these solvents when hot. The mother liquid from the erythritol is shaken out with ethylacetate and then supersaturated with sulphuric acid in the cold. This acid liquid is shaken out once with ether and then exhausted by shaking with ethyl acetate. The ethyl acetate takes up an acid which crystallizes out upon proper concentration of the solvent. Recrystallized from about six times its own weight of water, α, α' -dihydroxy- α -methyl- α' -isopropyladipic acid melts at 189° with the elimination of water.

Even in the cold, terpinene is readily attacked and destroyed by the chromic acid mixture prepared according to Beekmann's directions.²⁾ This property can be made use of when terpinene is to be removed from mixtures containing pinene, camphene, limonene, terpinolene, cineol, and pinol since these substances are stable toward this oxidizing agent in the cold.

¹⁾ Liebig's Annalen 362 (1908), 297; comp. also Gildemeister and Müller, Wallach-Festschrift, Göttingen 1909, p. 443.

²⁾ Berl. Berichte 27 (1894), 815.

Phellandrene.

Phellandrene belongs to those hydrocarbons $\text{C}_{10}\text{H}_{16}$ that are widely distributed. In nature it occurs in several modifications. According to Wallach¹⁾, phellandrene is defined as "a hydrocarbon $\text{C}_{10}\text{H}_{16}$, which when brought into contact with N_2O_5 in an indifferent, non aqueous solvent (ligroin) at a temperature below 0 — hence under conditions that exclude inversion as much as possible — yields *at once* a well characterized nitrite".

Of the natural phellandrenes the α - and the β -varieties should be kept quite distinct. Of the α -variety, the *d*- α -phellandrene has been found in gingergrass oil, schinus oil, bitter fennel oil, the Spanish dill herb oil, both Ceylon and Seychelle cinnamon oil, and elemi oil; the *l*- α -phellandrene in Australian eucalyptus oil and star anise oil.

β -Phellandrene has been found in water fennel oil (*d*-), in lemon oil, schinus oil, star anise oil, in the oil of *Eucalyptus amygdalina* and probably in coriander oil and cumin oil.

In most other instances when the presence of phellandrene has been reported, it does not become apparent which phellandrene it is that has been identified. In most instances, however, it appears to be α -phellandrene which appears to be accompanied by traces of β -phellandrene. Hence the conditions appear to be similar to those observed in connection with α - and β -pinene. In addition to the occurrences mentioned above, phellandrene has been found in the following volatile oils:

¹⁾ Liebig's Annalen 336 (1904), 10.

d-Phellandrene in Siberian pine-needle oil, in the oil from the wood of *Cæsalpinia Sappan* and in angelica root oil.

l-Phellandrene in the needle oil from *Picea excelsa*, the needle oil from *Pinus montana*, pimenta oil, bayberry oil from the Bermuda islands and in the oil from the seeds of *Monodora grandillora*.

Without reference to the optical rotation, the presence of phellandrene has been recorded in the oils of *Juniperus phænicea*, *Andropogon laniger*, eucema, ginger, pepper, magnolia, *Monodora Myristica*, *Cinnamomum pcdunculatum* (bark), cinnamon root, camphor, sassafras leaves, geranium, frankincense, *Eucalyptus acmenoides*, *angophoroides*, *capitellata*, *coriacea*, *crebra*, *Dawsoni*, *Delegatiensis*, *dives*, *fastigiata*, *Fletcheri*, *Iraxinoides*, *hæmastoma*, *loxophleba*, *Luehmanniana*, *macrorrhyncha*, *melanophloia*, *meliodora*, *microtheca*, *nigra*, *obliqua*, *oreades*, *ovallolia*, o. var. *lanceolata*, *pulverulenta*, *radiata*, *Risdoni*, *robusta*, *rostrata*, *siderophloia*, *sideroxylon* var. *pallens*, *Sieberiana*, *stellulata*, *vinivialis*, *virgata*, *vitreæ*, in German and English dill oil, in the oil of ajowan herb, and in the oils of peppermint, wormwood, goldenrod, and dog fennel.

The phellandrenes belong to the least stable of the terpenes. Hence, when it is desired to isolate phellandrene from a volatile oil or to identify it, the oil should not be distilled repeatedly under ordinary pressure, but should be fractionated under diminished pressure.

Synthetically, *α*-phellandrene was obtained by Harries and Johnson,¹⁾ also by Wallach.²⁾ However, the products obtained were not of unquestioned purity. The only crystalline derivatives of the phellandrenes, the nitrosites, do not lend themselves to the regeneration of the hydrocarbon. They are decomposed with alkali,³⁾ but no hydrocarbon $C_{10}H_{16}$ results. In the study of phellandrene, it is therefore necessary to be content with fractions rich in phellandrene. For this purpose the fraction 170 to 178 is usually taken. The properties of phellandrene, as recorded, pertain to such fractions.

¹⁾ Berl. Berichte 38 (1905), 1832.

²⁾ Liebig's Annalen 359 (1908), 283.

³⁾ Wallach, Liebig's Annalen 287 (1895), 374; 336 (1904), 30.

Of the constants observed, the following may here be mentioned:

l- α -Phellandrene from the oil of *Eucalyptus amygdalina*.¹⁾

b. p. 173 to 175 (754 mm.), 50 to 52 (5 mm.); d_{15} , 0.848; n_D^{20} , 1.47694.

d- α -Phellandrene from gingergrass oil:²⁾ b. p. 44 to 45 (4 mm.), 175 to 176 (754 mm.); d_{15} , 0.8565; n_D^{20} , 1.47694.

d- α -Phellandrene from clemi oil:³⁾ b. p. 61 (11 mm.); d_{15} , 0.844; n_D^{20} , 1.4732.

β -Phellandrene from water-fennel oil: b. p. 57 (11 mm.); d_{20} , 0.8520; n_D^{20} , 1.4788⁴⁾ and d_{15} , 0.848; $[\alpha]_D^{20}$, +14.45'; n_D^{15} , 1.4759.⁵⁾

The optical rotation is very variable. It is reduced by the action of sun light.⁶⁾

As already pointed out, phellandrene is relatively unstable. When heated to its boiling point it is polymerized. By the action of acids it is even more readily changed to inactive isomers. Thus by the action of hydrohalogen it is converted into dipentene, by alcoholic sulphuric acid into terpinene. When acted upon by halogen or hydrohalogen, liquid compounds mostly result. When oxidized with potassium permanganate, α -phellandrene yields the oily α -hydroxy- β -isopropylglutaric acid, which, upon further oxidation with lead peroxide and sulphuric acid, is converted into isopropylsuccinic acid. The oxidation products obtained from β -phellandrene are α -hydroxy- β -isopropyladipic acid and α -isopropylglutaric acid respectively.⁷⁾ Upon oxidation of β -phellandrene with a one percent. solution of potassium permanganate, Wallach⁸⁾ obtained, in addition to β -isopropylcyclohexanone, α -isopropylglutaric acid, isobutyric acid, and an oily glycol. When acted upon with dilute sulphuric acid, this glycol yielded tetra-

¹⁾ Observations made in the laboratory of Schimmel & Co.

²⁾ Report of Schimmel & Co. April 1904, 36.

³⁾ Wallach, Liebig's Annalen 336 (1904), 12.

⁴⁾ *Ibidem* 43.

⁵⁾ *Ibidem* 340 (1905), 2.

⁶⁾ Bacon, Philippine Journ. of Sc. 4 (1909), A. 101.

⁷⁾ Seimmler, Berl. Berichte 36 (1903), 1749.

⁸⁾ Liebig's Annalen 340 (1905), 12.

hydrocuminic aldehyde and some dihydrocuminic alcohol. When β -phellandrene is oxidized with oxygen from the air, α -isopropylcyclohexanone results.¹⁾

The only solid derivative of phellandrene is its nitrite resulting upon the addition of nitrous acid, hence this is used for its identification. Both phellandrenes yield two nitrites, which, as first pointed out by Schreiner,²⁾ are distinguished by their melting points. In order to ascertain whether an oil contains phellandrene, a solution of 5 g. of sodium nitrite in 8 g. water is placed beneath a layer of a solution of 5 cc. of the oil in 10 cc. of petroleum ether. 5 cc. of glacial acetic acid are then added while shaking the mixture for the purpose of generating the necessary nitrous acid. The voluminous crystalline magma is removed with the aid of a force filter, washed first with water and then with methyl alcohol, and finally purified by repeated solution in chloroform and subsequent precipitation with methyl alcohol.³⁾ The crude phellandrene consists of two modifications and the more soluble nitrite is lost in the above process. If it is desired to ascertain which phellandrene is present in a given oil, it is necessary, therefore, to purify with the aid of acetone.⁴⁾ When precipitated fractionally with water, the nitrite of α -phellandrene can be separated into its two modifications melting respectively at 112 to 113 (or 113 to 114) and 105; β -phellandrene into its two modifications melting at 102 and 97 to 98° respectively. All of these have different angles of rotation, partly dextrogyrate, partly laevogyrate.

Unlike terpinene nitrosites, the phellandrene nitrites cannot be converted into nitrolamines. When treated with sodium alcoholate, α -phellandrene nitrite yields nitro- α -phellandrene. Upon reduction with zinc and glacial acetic acid, this yields carvotanacetone and dihydrocarvylamine. The more energetic reduction with sodium in alcoholic solution yields tetrahydrocarvone and tetrahydrocarvylamine.⁵⁾ β -Phellandrene, when treated with sodium alcoholate, yields nitro- β -phellandrene. When reduced, this is con-

¹⁾ Liebig's Annalen 343 (1905), 29.

²⁾ Pharmaceutical Archives 4 (1901), 90.

³⁾ Wallach and Gildemeister, Liebig's Annalen 246 (1888), 282.

⁴⁾ Wallach, Liebig's Annalen 336 (1904), 13.

⁵⁾ *Ibidem* 30, 44.

verted into dihydrocuminic aldehyde (m. p. of the semicarbazone 200 to 202'), tetrahydrocuminylamine and euminyllamine.

For the oxidation of *β*-phellandrene the oxidation with a one percent. solution with potassium permanganate may also be resorted to, yielding a syrupy glycol (b. p. 150 at 10 mm.).¹⁾ When heated with dilute sulphuric acid, this glycol is converted into dihydrocuminic alcohol and tetrahydrocuminic aldehyde (h. p. 220 to 230; d_{20} 0.93; n_{D20} 1.4903; m. p. of the semicarbazone 204 to 205). As byproducts *isopropyl-1-cyclohexene-2-one-4*, and α -*isopropylglutaric acid*, and *isohutyric acid* result.

SESQUITERPENES.

In addition to the terpenes $C_{10}H_{16}$, the higher boiling fractions of many volatile oils, viz., those between 250 and 280, contain hydrocarbons corresponding to the formula $C_{15}H_{24}$, which have been named sesquiterpenes. Of these a considerable number have been isolated, but few have been investigated to any extent.

A few oils consist almost exclusively of sesquiterpenes. In most instances, however, they play but a secondary role. Their occurrence is so general that they must be regarded as belonging to the most common constituents of the volatile oils.

Artificially also sesquiterpenes have been prepared from the alcohols $C_{15}H_{26}O$ which accompany the former in many volatile oils. These alcohols seem to stand in the same relation to the sesquiterpenes as does terpineol, $C_{10}H_{18}O$ to the hydrocarbon $C_{10}H_{16}$. Nevertheless the addition of the elements of a molecule of water to a hydrocarbon $C_{15}H_{24}$ by means of the glacial acetic acid-sulphuric acid mixture has been carried out successfully in but one instance. Whether the hydrocarbons $C_{15}H_{24}$ obtained by the dehydration of the "sesquiterpene alcohols" are identical with the natural sesquiterpenes, has not yet been determined.

In general, the boiling points of the sesquiterpenes lie between 250 and 280°; their density 0.86 and 0.93, as a rule above 0.90. In most instances they are slightly colored. They are more viscid than the terpenes and have a faint odor. In part

¹⁾ Liebig's Annalen 340 (1903), 12.

they resinify as readily as do the terpenes and they are difficultly soluble in alcohol. As unsaturated hydrocarbons they add halogens, hydrohalogens, NOCl , N_2O_3 and N_2O_4 . Some of them yield crystalline addition products which can be used for their identification. Their oxidation products, however, remain practically unexamined.

As to their constitution, nothing definite is known. Hence we are dependent on their physical properties for their classification. A better knowledge of the sesquiterpenes is rendered more difficult from the fact that the only method suitable for their isolation, namely that of fractional distillation, precludes the preparation of pure products. Based on their molecular refraction and relative density, they are classified as aliphatic, monocyclic, dicyclic and tricyclic sesquiterpenes.¹⁾ As with the terpenes, these groups are characterized by regularity with reference to boiling point and more particularly to density.

| | Mol.-Refr. (calc.) | Density (15°) |
|--------------------------|--------------------|------------------|
| aliphatic sesquiterpenes | 69,5 | about 0,86, |
| monocyclic " | 67,76 | " 0,875 to 0,89, |
| bicyclic " | 66,15 | " 0,90 " 0,92, |
| tricyclic " | 64,45 | " 0,93 " 0,94. |

In as much as only a few sesquiterpenes have been obtained in a pure state, it is frequently difficult to ascertain to which of the above groups they belong. The conditions of isomerism are even more complicated than among the terpenes. Nevertheless it is not at all probable that the 60 to 70 known sesquiterpenes are all different. No doubt, many of these will be found identical as soon as it becomes possible to obtain a clear view over this field as over that of the terpenes, since the terpenes have become one of the best known groups of organic compounds.

In the compilation which follows only those representatives of the sesquiterpenes will be discussed in detail the characterization of which has been made possible.

¹⁾ Theoretically tetracyclic sesquiterpenes are also possible. In as much as none of these have yet been isolated, this mere reference to the group may suffice.

Aliphatic Sesquiterpenes.

To this group there possibly belongs the "light sesquiterpene" which was isolated by Schimmel & Co.¹⁾ from Ceylon citronella oil and which possesses the following properties:

B. p. under atmospheric pressure 270 to 280° with much decomposition, at 137° under 15 mm. pressure; $d_{15} = 0.8643$; $n_{D,15} = 1.28$; $n_{D,15} = 1.51849$.

This sesquiterpene, of which no derivatives are known, is very unstable. When exposed to the air, it resinifies within a few days to a syrupy liquid.

*Monocyclic Sesquiterpenes.**Bisabolene.*

Bisabolene was first found by Tscholka²⁾ in Bisabol myrrh oil. The same name was given later to sesquiterpenes which had originally been known by other designations, but which had been found to be identical with it.

In addition to its occurrence in Bisabol myrrh oil, it has been found in Siberian pine-needle oil, in the oil of *Piper Volkensii*, in camphor oil and in the oils of limette, lemon, bergamot and opopanax.

For the hydrocarbon fractionated from lemon oil, Gildemeister and Müller³⁾ ascertained the following constants:

B. p. 110 to 112° (4 mm.); $d_{15} = 0.8813$; $n_{D,15} = 1.28$; $n_{D,20} = 1.49015$. For the inactive sesquiterpene regenerated from the tri-chlorhydrate by means of sodium acetate and glacial acetic acid, they ascertained the following constants:

B. p. 261 to 262° (751 mm.); $n_{D,15} = 1.28$; $d_{15} = 0.8759$; $n_{D,20} = 1.4901$.

With hydrogen chloride, bisabolene yields a tri-chlorhydrate, $C_{15}H_{24}3HCl$, which melts at 79 to 80° and which, according to Tscholka is optically active ($[\alpha]_D$ (— or —?) 35°17' in chloroform

¹⁾ Report of Schimmel & Co. October 1899, 23.

²⁾ Arch. der Pharm. 25 (1897), 292.

³⁾ Wallach-Festschrift, Göttingen 1909, p. 448; Report of Schimmel & Co. October 1909, 64.

solution), but which, according to Gildemeister and Müller, is inactive. Neither a solid nitroschloride, nor a nitrosite, nor a nitrosate could be obtained from bisabolene. It adds 6 atoms of bromine. Whether the hexabromide, obtained by Schmidt and Weiling¹⁾ from the oil of *Piper Volkensii*, and melting at 154° is a derivative of bisabolene remains to be proven.

For the characterization of bisabolene, the trichlorhydrate, obtained by passing gaseous hydrogen chloride into an ethereal solution of the sesquiterpene, is especially suited. Upon evaporation of the ether, it separates in handsome crystals, which can be further purified by recrystallization from alcohol.

Zingiberene.

This sesquiterpene, first found by Tresh²⁾ in ginger oil, was later examined by v. Soden and Rojahn,³⁾ also by Schreiner and Kremers.⁴⁾ The last mentioned investigators ascertained the following constants:

B. p. abt. 270° (with decomposition), 160 to 161° (32 mm.); d_{20}^{20} 0.8731; $[\alpha]_D^{20}$ — 73.38°; n_D^{20} 1.49399.

The nitroschloride melts at 96 to 97°, the nitrosite at 97 to 98°, the nitrosate at 86 to 88° and the dihydrochloride at 168 to 169°. For the characterization of this hydrocarbon its dihydrochloride can be prepared by passing hydrogen chloride into its solution in glacial acetic acid. After standing for two days, it crystallizes out in fine needles. The nitrosate also can be used for its identification since, according to Schreiner and Kremers, the yield obtained almost equals the theoretical yield.

Bicyclic Sesquiterpenes.

Cadinene.

The best known representative of this subgroup as of the group of the sesquiterpenes in general is the cadinene, which is widely distributed and which occurs in both optical modifications.

¹⁾ Berl. Berichte 39 (1906), 652.

²⁾ Pharmaceutical Journ. III. 12 (1882), 243.

³⁾ Pharm. Ztg. 45 (1900), 414.

⁴⁾ Pharmaceutical Archives 4 (1901), 63; Chem. Zentralbl. 1901, II. 1226.

d-Cadinene has thus far been found in the oil of the Atlas cedar, and probably also in West Indian sandalwood oil.

l-Cadinene has been found in cade oil, from which it derives its name, and in the oils of cypress, cubcbs, paracoto bark, angostura bark and cedrella wood.

In most of the references on the occurrence of cadinene, the direction of the rotation is not mentioned, thus in German and Swedish oils from *Pinus sylvestris*, the oils from *Pinus montana*, of *Picea excelsa*, juniper berries, savin, cedar leaves, cedar wood, lemongrass, pepper, betel, ylang-ylang, camphor, *Amorpha fruticosa*, frankincense, African copaiha balsam (see below¹⁾), asafetida, galbanum, American peppermint, patchouli, wormwood and goldenrod.

Cadinene can be obtained in a relatively pure condition since it yields a well crystallized dihydrochloride from which it can be regenerated, like the terpenes, by heating with aniline or with sodium acetate in glacial acetic acid solution.²⁾ For the hydrocarbon thus regenerated, Wallach found the following constants:

B. p. 272 (uncorr.³⁾), 274 to 275 ; d_{20} 0.918; $[\alpha]_D^{20}$ — 98.56' ; n_D^{20} 1.50647.⁴⁾

Schimmel & Co. found:

B. p. 271 to 273 ; d_{15} 0.9215; $[\alpha]_D^{15}$ — 105° 30'.

The optical rotation varies considerably. In a number of instances where the natural sesquiterpene has been pronounced an active modification of cadinene, it has not been definitely established whether the hydrocarbon is really identical with cadinene, or whether it has been converted into a cadinene derivative by the action of hydrogen chloride. This is true e. g. of the sesquiterpenes in West Indian sandalwood oil and African copaiha balsam. It is at least noteworthy that a derivative of *l*-cadinene should have been obtained from these dextrogyrate oils, whereas the dextrogyrate hydrocarbon from Atlas cedar oil yielded derivatives of *d*-cadinene.

¹⁾ Wallach, Liebig's Annalen 298 (1887), 84.

²⁾ Liebig's Annalen 271 (1892), 303.

³⁾ *Ibidem* 252 (1889), 150; 271 (1892), 297.

When exposed to air, cadinene resinifies very readily with the formation of a polymerization product. When heated for a long time with dilute sulphuric acid, cadinene is altered, whereas the action of hydrohalogen appears to produce no essential change since the optical activity remains unaltered. Prolonged heating to 200° likewise changes cadinene. An isomeric hydrocarbon is thus produced with the following properties: b. p. 145 to 148° (20 mm); d_4^{20} , 0.9061; $[\alpha]_D^{20}$, -2.80°; $n_{D,20}$, 1.5041.¹⁾

With nitrosyl chloride and nitrogen tetroxide, cadinene yields crystalline addition products. The nitrosochloride, of which only a small yield is obtained, melts at 93 to 94°; the nitrosate, which affords a better yield, melts at 105 to 110°.

Especially characteristic are the crystalline addition products obtained with two molecules of hydrohalogen, of which the dichlor- and the dibromhydrate are used for identification.

For the purpose of preparing the dichlorhydrate, fractions 260 to 280° are diluted with twice their volume of ether, well cooled and saturated with hydrogen chloride. After prolonged standing, the ether is in part distilled off, in part allowed to evaporate spontaneously. The crystals of dichlorhydrate thus obtained are dried on porous plate, washed with alcohol to remove oily impurities and recrystallized from acetic ether in which they can readily be dissolved with the aid of heat. The pure compound melts at 117 to 118°. It is optically active, $[\alpha]_D^{20}$, -37.27° in a 5 p. c. chloroform solution.

The dichlorhydrate can also be prepared with the aid of glacial acetic acid that has been saturated with hydrogen chloride. This modification is especially adapted to the preparation of the dibromhydrate (m. p. 124 to 125°) and the diiodhydrate (m. p. 105 to 106°). The glacial acetic acid solution of the hydrohalogen is added to the glacial acetic acid solution of the hydrocarbon.

Caryophyllene.

A second well characterized hydrocarbon, which belongs to the bicyclic group of sesquiterpenes, is the caryophyllene. However, it is not as common as cadinene. Up to the present time it has

¹⁾ Lepeschkin, Journ. russ. phys. chem. Ges. 40 (1908), 698. According to Chem. Zentralbl. 1908, II. 1354.

been found in appreciable amounts in the oil of cloves and the oil of clove stems, also in copaiba balsam oil. Furthermore, it has been found in the oils of pepper, betel, Ceylon cinnamon, Seychelles cinnamon (?), cinnamon root, canella alba, pimenta and lavender.

Up to the present time, caryophyllene has not been prepared in a pure state. The physical constants recorded refer to fractions of clove oil or of oil of clove stems that were not perfectly pure. Caryophyllene obtained by distillation only from oil of cloves mostly contains some acetugenol¹⁾ from which it can be freed by saponification with alcoholic potassa. The sesquiterpene from oil of clove stems does not contain this impurity.

For the caryophyllene from oil of cloves

Wallach²⁾ found: B. p. 258 to 260°; d_{15}^4 0,9085; n_D^{20} 1,50094.

Erdmann³⁾ found: B. p. 119 to 120 (9 mm.), 123 to 124° (13 mm.), 258 to 259 (752 mm.); d_{20}^{20} 0,9038.

Kremers⁴⁾ found: d_{20}^{20} 0,9032; $[\alpha]_{D_{120}}^{20}$ - 8,74; $n_{D_{120}}^{20}$ 1,50019.

For the caryophyllene from Ceylon cinnamon oil, Walbaum and Hütthig⁵⁾ found: B. p. 260 to 261°; d_{15}^{20} 0,9047; α_D^{20} - 7° 20'.

More recent investigations by Deussen and his collaborators⁶⁾ would seem to indicate that the fractions of clove stem oil designated caryophyllene consist of at least two isomers, an optically inactive α -caryophyllene, and an active β -caryophyllene, both of which have been characterized by derivatives.

According to Schreiner and Kreiners⁷⁾ a dichlorhydrate, crystallizing in needles and melting at 69 to 70°, results from the action of hydrogen chloride upon the caryophyllene-containing fractions of oil of cloves. From the crude caryophyllene of clove stem oil, Schimmel & Co. obtained an active chloride of like melting point. Other investigators obtained from caryophyllene-containing fractions of various oils either liquid chlorides, or chlorides of a different melting point.

¹⁾ E. Erdmann, Journ. f. prakt. Chem. II. 56 (1897), 146.

²⁾ Liebig's Annalen 271 (1892), 298.

³⁾ Journ. f. prakt. Chem. II. 56 (1897), 146.

⁴⁾ Pharmaceutical Archives 1 (1898), 211.

⁵⁾ Journ. f. prakt. Chem. II. 66 (1902), 54.

⁶⁾ Liebig's Annalen 356 (1907), 1; 359 (1908), 245; 369 (1909), 41.

⁷⁾ Pharmaceutical Archives 2 (1899), 296; Proceed. Americ. Pharm. Ass. 47 (1899), 158.

By the action of nitrosyl chloride on caryophyllene from clove stem oil, there results a nitrosochloride melting at about 160°. Upon fractional crystallization, however, it can be resolved into two compounds: an inactive α -caryophyllene nitrosochloride (m. p. 177°) and an active β -caryophyllene nitrosochloride (m. p. 159°). Corresponding with these nitrosochlorides there are an α -nitrol-benzylamine base melting at 126 to 128° and a β -nitrolamine base melting at 172 to 173°. Both of these can also be obtained from the mixture of nitrosochlorides. By splitting off hydrogen chloride the nitrosochlorides yields the corresponding nitroso-caryophyllenes, of which the α -form melts at 116°, the β -form at 120 to 121°.

With nitrous acid anhydride, caryophyllene forms an optically active nitrosite, which crystallizes in blue needles, melts at 115°, and is readily changed to other compounds by the action of solvents. There is also known an active caryophyllene nitrosate, which can be obtained by the action of amyl nitrite and nitric acid on caryophyllene or by the oxidation of the blue nitrosite with chromic acid. It melts at 130.5°. Nitrosates of caryophyllene with different melting points are presumably derived from the α -form.

Upon oxidation with permanganate there results, according to Deussen¹⁾ and Haarmann²⁾, in addition to a glycol $C_{11}H_{22}O_4$ (m. p. 120°), a ketoacid $C_{10}H_{16}O_3$ (semicarbazone melts at 186°), a monobasic acid $C_8H_8O_4$ (m. p. 179.5 to 180.5°), and a neutral substance $C_{10}H_{14}O_3$ (m. p. 145 to 146°). The liquid acids which result in this oxidation yield dimethyl succinic acid upon further oxidation.

When acted upon with glacial acetic acid-sulphuric acid mixture, caryophyllene yields a hydrate $C_{15}H_{26}O$, caryophyllene alcohol, melting at 94 to 96°. This alcohol, the phenyl urethane of which melts at 136 to 137°, is optically inactive.

It is noteworthy that upon the dehydration of caryophyllene alcohol caryophyllene is not regenerated, but that an isomeric tricyclic hydrocarbon $C_{15}H_{24}$, the clovene results. This differs materially in its properties from caryophyllene, but has not yet been found in volatile oils.

¹⁾ Liebig's Annalen 359 (1908), 258; 369 (1909), 52; Berl. Berichte 42 (1909), 376, 680.

²⁾ Berl. Berichte 42 (1909), 1062.

When attempting to identify caryophyllene, it should be remembered that the nitrosochloride and the nitrosate are derived from a different hydrocarbon than the blue nitrosite.¹⁾ Hence the precaution should be taken to prepare the nitrosite as well as the nitrosochloride or nitrosate.

For the preparation of the nitrosochloride, 5 ccm. of alcoholic hydrogen chloride are added to a well cooled mixture of 5 ccm. caryophyllene, 5 ccm. acetic ether, 5 ccm. alcohol and 5 ccm. ethyl nitrite. Under the influence of sunlight the nitrosochloride soon separates.

For the preparation of the nitrosite, 5 ccm. of glacial acetic acid are cautiously added to a mixture of 5 ccm. caryophyllene, 12 ccm. petroleum ether and 5 ccm. of a saturated solution of sodium nitrite. In the cold the nitrosite crystallizes out.

For the preparation of the nitrosate, a solution of 5 ccm. of concentrated nitric acid in 5 ccm. glacial acetic acid are cautiously added to a well cooled mixture of 5 ccm. caryophyllene, 5 ccm. glacial acetic acid and 5 ccm. ethyl nitrite. Finally alcohol is added and after 2 hours the nitrosate separates out.

Quite convenient is the preparation of caryophyllene alcohol.²⁾ 25 g. of the hydrocarbon are dissolved in a mixture of 1000 g. glacial acetic acid, 25 g. concentrated sulphuric acid and 40 g. water. After prolonged heating of the mixture, the more readily volatile products are removed by distillation with steam, after which the pure alcohol is obtained by continued distillation.

Selinene.

While investigating the highest boiling fractions of clove seed oil, Ciamician and Silber³⁾ found a sesquiterpene which, however, they did not further characterize. When this sesquiterpene was later on examined in the laboratory of Schimmel & Co. it was ascertained that it was not identical with any of the known sesquiterpenes and was named selinene.

¹⁾ Deussen, Liebig's Annalen 356 (1907), 1; 359 (1908), 245.

²⁾ Wallach, Liebig's Annalen 271 (1892), 288.

³⁾ Berl. Berichte 30 (1897), 492, 501.

Selinene constitutes about 20% of celery seed oil and can be obtained from fraction 265 to 273. After repeated fractionation over sodium, it possessed the following properties:

B. p. 120 to 121 (6 mm.); $d_{17.8}$ 0.9197; $\alpha_D + 35^\circ 11'$; $n_{D,20}$ 1.49863.

Regenerated from its dichlorhydrate, it possessed the following properties:

B. p. 268 to 272°; d_{15} 0.9232; d_{20} 0.9196; $\alpha_D + 49^\circ 30'$; $n_{D,20}$ 1.50483; mol. refr. 65.82, corresponding to $C_{18}H_{24}$ 66.15.

The dichlorhydrate referred to is obtained by passing gaseous hydrogen chloride into an ethereal solution of the sesquiterpene. It crystallizes in fine needles, which when pure melt at 72 to 74°; $[\alpha]_D^{25} + 18$ (in 4.07% chloroform solution). Selinene dichlorhydrate differs from the caryophyllene dichlorhydrate though both have similar melting points. Upon splitting off hydrogen chloride, selinene is regenerated, whereas caryophyllene dichlorhydrate, when submitted to like treatment, yields a new hydrocarbon.

With nitrosylchloride or oxides of nitrogen, no solid derivatives could be obtained.

Judging from its molecular refraction, selinene belongs to the bicyclic group of sesquiterpenes.

Humulene.

This sesquiterpene, which was first discovered by Piccard, and which up to the present time has been found only in oil of hops and oil of poplar buds, closely resembles caryophyllene. Thus far the attempts to regenerate humulene from one of its derivatives have not been successful. Hence the constants had to be ascertained in connection with more or less pure fractions. Chapman,¹⁾ who has devoted much study to the characterization of this sesquiterpene, records the following:

B. p. 263 to 266° (760 mm.); d_{15} 0.9001; $\alpha_D - 0.5^\circ$; n_D 1.5021.

The hydrocarbon obtained from poplar bud oil was slightly dextrogyrate. It is probable, however, that humulene itself is optically inactive and that the slight rotation was due to impurities.

¹⁾ Journ. chem. Soc. 67 (1895), 54.

Hydrogen chloride, when added, yields a liquid dihydrochloride, bromine an oily tetrabromide. Upon hydration an alcohol results. Nitrosyl chloride is added with the formation of a nitrosochloride melting at 164 to 165°, respectively at 164 to 170°. The nitrobenzylamine base melts at 136°, respectively at 132 to 133°; the nitropiperidine base at 153°. Nitrous acid is added with the formation of a nitrosite melting at 120 to 121°, and of an isonitrosite melting at 166 to 168°. Both of these, when treated with sodium ethylate, yield nitroso- or isonitrosohumulene, b. p. 185 to 195° (13 mm.). The nitrosate, m. p. 162 to 163°, is also known. Humulene can be identified by means of its nitrosochloride in the usual manner.

Santalene.

In addition to the two santalols, East Indian sandalwood oil contains two sesquiterpenes, α - and β -santalene, so named by Guerbet.¹⁾

α -Santalene shows the following properties:

B. p. 252 to 252.5 (uncorr.), 253 to 254° (corr.); d_4^{20} , 0.9134; n_D^{20} , 1.498 (Guerbet).

B. p. 118 to 120° (9 mm.); d_4^{20} , 0.8984; n_D^{20} , 1.491 (Semmler.²⁾)

β -Santalene shows the following properties:

B. p. 261 to 262 (uncorr.), 263 to 264° (corr.); d_4^{20} , 0.9139; n_D^{20} , 1.4855 (Guerbet).

B. p. 125 to 127° (9 mm.); d_4^{20} , 0.892; n_D^{20} , 1.4932 (Semmler).

According to Semmler, α -santalene is to be regarded as a tricyclic sesquiterpene with one double bond, β -santalene as bicyclic with two double bonds.

α -Santalene combines with hydrochloric acid to a liquid hydrochloride. With nitrosylchloride a nitrosochloride, m. p. 122°, results, the nitropiperidine base of which melts at 108 to 109°. When oxidized with ozone, Semmler obtained the bicyclic eksantalal (b. p. 112 to 116° (9 mm.); d_4^{20} , 1.00; n_D^{20} , 1.4872) which likewise results upon oxidation of α -santalol.

¹⁾ Compt. rend. 190 (1900), 417, 1324; Bull. Soc. chim. III. 23 (1900), 217 and 540.

²⁾ Berl. Berichte 40 (1907), 3321.

p-Santalene adds two molecules of hydrogenchloride with the formation of a liquid dihydrochloride.¹⁾ The nitrosochloride exists in two isomeric forms, which melt at 152° and 106° respectively, and to which two nitropiperidine bases (m. p. 101 and 104 to 105° respectively) correspond. When oxidized with ozone a dicyclic aldehyde results.

Hence the two santalenes appear to stand in genetic relationship to the two santalols. The two santalenes can be identified by means of their nitrosochlorides and by their oxidation products with ozone.

Isosantalenes. The hydrocarbons resulting upon dehydration of the santalols are, however, different from the santalenes. From the crude santalol Chapotcaut²⁾ obtained two hydrocarbons, one $C_{15}H_{24}$, b. p. 260 and another $C_{15}H_{22}$, b. p. 245°. The hydrocarbons obtained from the two santalols, Guerbet³⁾ named *iso*-santalenes and recorded the following properties:

α-Isosantalene: b. p. 255 to 256; n_D^{20} 1.02.

β-Isosantalene: b. p. 259 to 260; n_D^{20} 1.01.

It is doubtful whether these two hydrocarbons are sesquiterpenes.

Of the lesser known sesquiterpenes the following may here be mentioned:

Atractylene.

This sesquiterpene, which has not yet been found in volatile oils, was obtained by Gadamer and Amenomiya¹⁾ by the action of dehydrating agents on atractylol, a sesquiterpene alcohol.

B. p. 125 to 126 (10 mm.); d_{15}^{20} 0.9154; n_D^{20} 1.50893.

The liquid dihydrochloride, prepared from atractylol, when heated with aniline yields a hydrocarbon which differs from atractylene.

Caparrapene.

Caparrapene is a sesquiterpene which has been obtained by Tapia²⁾ by the action of dehydrating agents on caparrapiol, a

¹⁾ von Soden and Müller, Pharm. Ztg. 44 (1899), 259.

²⁾ Bull. Soc. chim. II, 37 (1882), 303.

³⁾ Ibidem III, 23 (1900), 543.

⁴⁾ Arch. der Pharm. 241 (1903), 33.

⁵⁾ Bull. Soc. chim. III, 19 (1898), 638.

sesquiterpene alcohol occurring in the volatile oil from *caparrapi-halsani*. The hydrocarbon is a colorless liquid which is readily colored yellow when exposed to light. The following constants are recorded:

B. p. 240 to 250 ; d_{16}^4 0,9019; $[\alpha]_D^{25}$ - 2,21'; n_D^{25} 1,4953.

When hydrogen chloride is passed into the glacial acetic acid solution of the sesquiterpene, an active dihydrochloride results melting at 83 .

Guajene.

Upon dehydrating guajol, a new sesquiterpene alcohol isolated by Schimmel & Co.¹⁾ from guajac wood oil, with zinc chloride, Wallach and Tittle²⁾ obtained a new sesquiterpene the properties of which did not correspond with those of any of the known ones.

B. p. 124 to 128 (13 mm.); d_{20}^4 0,910; n_D^{20} 1,50144.

For the sesquiterpene prepared from guajol according to Tchugaeff's xanthogenate method, A. Giandurin³⁾ records the following properties:

B. p. 124 (11 mm.); d_4^{20} 0,9133; d_4^{25} 0,8954; $[\alpha]_D^{25}$ - 66,11 ; $n_{D,25}^{25}$ 1,49468; mol. refr. 66,46.

Guajene obtained by heating guajol with potassium acid sulphate possesses, according to Gadamer and Amenomiya⁴⁾ the following properties:

B. p. 123 to 124 (9 mm.); d_4^{20} 0,9085; $[\alpha]_D^{25}$ - 40,35 ; $n_{D,25}^{25}$ 1,50049; mol. refr. 66,2.

Hence, guajene appears to belong to the bicyclic sesquiterpenes. Crystalline derivatives are not known.

Sesquiterpene from Cade Oil.

According to Tröger and Feldmann,⁵⁾ oil of cade contains, in addition to cadinene, a second, inactive sesquiterpene boiling between 250 to 260 . When treating oil of cade with hydrogen

¹⁾ Report of Schimmel & Co. April 1892, 56; April 1893, 42.

²⁾ Liebig's Annalen 279 (1894), 396.

³⁾ Berl. Berichte 41 (1908), 4363.

⁴⁾ Arch. der Pharm. 241 (1903), 43.

⁵⁾ Arch. der Pharm. 296 (1898), 692.

chloride, N. Lepeschkin¹⁾ obtained in addition to cadinenedihydrochloride, a liquid chloride. For the sesquiterpene regenerated from this liquid chloride, he records the following properties:

B. p. 262 to 266 (760 mm.); 135 to 140 (20 mm.); d_{20}^{20} 0,9204; $n_{D,20}$ 1,5159.

Crystalline derivatives could not be obtained. Upon heating with hydrogen iodide to 200°, Lepeschkin obtained a hydrocarbon (b. p. 250 to 258; d_{20}^{20} 0,8946; $n_{D,20}$ 1,4972) which he supposes may be identical with humulene. However, according to Schindelmeyer,²⁾ it is a mixture of tetrahydrocadinene, cadinene and a new, optically inactive sesquiterpene. Schindelmeyer is further of the opinion that the sesquiterpene of Lepeschkin still contains cadinene. For the pure sesquiterpene he records the following constants:

B. p. 263 to 265; d_{20}^{20} 0,908; α_D^{20} 0; n_D 1,5006.

None of these investigators, however, succeeded in characterizing this new sesquiterpene.

Sesquiterpene from Minjak-Lagam-Balsam Oil.

According to Haussner³⁾ the oil of Lagam balsam, which is closely related to gurjun balsam, consists almost exclusively of sesquiterpenes:

B. p. 249 to 251; d_{15}^{15} 0,923; α_D^{15} -9,9.

The sesquiterpene is a light colored oil which resinifies quickly when exposed to the air. With hydrogen chloride it yields a chloride $C_{15}H_{21} \cdot 3HCl$, which crystallizes in long needles and which melts at 114°.

The formation of a trichlorohydrate from a sesquiterpene with a density of 0,923 is somewhat strange. Aside from this, the properties of the sesquiterpene as well as those of its chloride would seem to indicate cadinene.

¹⁾ Journ. russ. phys. chem. Ges. 40 (1908), 126. According to Chem. Zentralbl. 1908, I. 2040.

²⁾ Journ. russ. phys. chem. Ges. 40 (1908), 181. According to Chem. Zentralbl. 1908, II. 598.

³⁾ Arch. der Pharm. 221 (1883), 245.

*Sesquiterpene from the Oil
of the Bark of Ocotea usambarensis.*

According to Schmidt and Weilingcr,¹⁾ the sesquiterpene from this oil has the following properties:

b. p. 136 to 142 (12 mm.); d_{20}^4 0.915; n_D^{20} +7.46'; n_D^{15} 1.505.

When acted upon with hydrogen chloride, a dihydrochloride (m. p. 116 to 117) results which is not identical with cadinene dihydrochloride.

Tricyclic Sesquiterpenes.

Cedrene.

The term cedrene was originally applied to a sesquiterpene obtained by the dehydration of cedrol.²⁾ Upon finding a similar sesquiterpene in oil of cedar, this likewise was designated cedrene. In as much as the identity of these two hydrocarbons has not been proven conclusively, it is best to treat them separately.

The constants of the natural cedrene are recorded as follows:³⁾

b. p. 124 to 126 (12 mm.); d_{20}^4 0.9354; n_D^{20} -55; n_D^{15} 1.50233.

Natural cedrene has been examined by a number of investigators, more recently particularly by Semmler and Hoffmann.⁴⁾ Upon oxidation with chromic acid in glacial acetic acid solution, cedrene, $C_{15}H_{24}O$, results, which boils at 148 to 151° (11 mm.) and upon reduction is converted into *isocedrol* (b. p. 148 to 151 at 9 mm.). Upon oxidation with permanganate in acetone solution, cedrene yields a glycol, $C_{15}H_{26}O_2$, m. p. 160°; a diketone or a ketoaldehyde $C_{15}H_{24}O_2$, the semicarbazone of which melts at 234°; and a cedrene keto acid, $C_{15}H_{24}O_3$, the semicarbazone of which melts at 245°, the oxime between 180 to 190°.

When oxidized with ozone, cedrene yielded essentially the same products. For its identification, the oxidation with permanganate is resorted to.

¹⁾ Berl. Berichte 39 (1906), 752.

²⁾ Walter, Liebig's Annalen 39 (1841), 247.

³⁾ The constants of the artificial cedrene are recorded in the table of the artificially prepared sesquiterpenes on p. 346.

⁴⁾ Berl. Berichte 40 (1907), 3521.

Clovene.

Upon dehydration with zinc chloride or phosphorus pentoxide of the caryophyllene alcohol, obtained by hydration of the hydrocarbon, Wallach¹⁾ secured the clovene, a sesquiterpene thus far not found in volatile oils.

B. p. 261 to 263°; d_4^{20} , 0.930; n_D^{20} , 1.50066; mol. refr. 64.77.

Upon hydration, clovene is not again converted into caryophyllene hydrate. For its identification a comparison of the physical constants has to be resorted to. By the action of para formaldehyde on clovene, Genvresse²⁾ obtained an alcohol $C_{15}H_{22}CH_2OH$, m. p. 170 (12 mm.); d_4^{20} , 1.001; n_D^{20} , 1.407 (in a 6.03 p. c. chloroform solution); n_D^{20} , 1.508. This ought to be suited to the identification of the hydrocarbon.

Heerabolene.

A sesquiterpene, probably tricyclic, has been found in Heerabol myrrin oil by O. v. Friedrichs³⁾ and designated heerabolene by him.

B. p. 130 to 136° (16 mm.); d_4^{20} , 0.943; n_D^{20} , 1.412°; n_D^{20} , 1.5125; mol. refr. 64.98.

Neither a characteristic bromide, nor a solid nitrosochloride or nitrosate could be obtained. With hydrogen chloride, however, a dihydrochloride melting at 98 to 99° resulted. As is the case with the sesquiterpene of galangal oil, the hydrogen chloride appears to have caused the cleavage of a cycle.

Heveene.

This sesquiterpene is obtained, together with isoprene and dipentene, upon the destructive distillation of caoutchouc or gutta percha.⁴⁾ Thus, 5 ko. of para caoutchouc⁵⁾ yield about

¹⁾ Liebig's Annalen 271 (1892), 292.

²⁾ Compt. rend. 138 (1904), 1228.

³⁾ Arch. der Pharm. 245 (1907), 208.

⁴⁾ Williams, Jahresber. d. Chem. 1900, 495; comp. also Beilstein, Handbuch d. org. Chem. 3rd ed., vol. 3, p. 538.

⁵⁾ G. Bouchardat, Bull. Soc. chim. II. 24 (1875), 108. Comp. also A. Bouchardat, Liebig's Annalen 27 (1838), 30; Himly, *ibidem* 27 (1838), 40.

250 g. isoprene, 2000 g. dipentene and 600 g. heveene.¹⁾ To a smaller extent polyterpenes also are formed. Bouehardat records 255 to 265° as boiling temperature. With hydrogen chloride a readily decomposable monhydrochloride $C_{15}H_{21}HCl$ is stated to be formed.

In the tables which follow, those sesquiterpenes are mentioned which have been found in volatile oils and of which some of the physical constants are known and which do not appear to be identical with known, well characterized sesquiterpenes.

| Sesquiterpene from | B. p. | d | n_D | n_D | Remarks |
|---|------------|----------------------------------|-----------------------------------|---------|--|
| Ageratum oil ²⁾ | 260 | — | — | — | — |
| Angelica root oil ³⁾ | 240 to 270 | — | — | — | — |
| Angostura bark oil ⁴⁾ (Gaipeene) | 255 to 260 | 0,912 (15) | + 0 | 1,50513 | With hydrogen chloride, readily decomposable liquid products are formed |
| Oil from the leaves of <i>Amorpha fruticosa</i> ⁵⁾ | 250 to 260 | 0,916 (15) | — | 1,50652 | The presence of calimene has also been proven |
| Oil from the rhizome of <i>Aralia nudicaulis</i> (Araliene) ⁶⁾ | 260 to 270 | 0,9086 (20) | — 7 to 8 (benzene solution) | 1,49936 | |
| Boldo leaf oil ⁷⁾ | 265 to 275 | — | 7 | — | — |
| Calamus root oil ⁸⁾ | 255 to 258 | 0,942 (0) 0,9323 (20) | — | — | — |

¹⁾ The name heveene was suggested by Bouehardat from the name of the plant *Hevea guianensis* which yields the caoutchouc.

²⁾ van Romburgh, Report of Schimmel & Co. April 1898, 53.

³⁾ Ciamician and Silber, Berl. Berichte 29 (1896), 1811.

⁴⁾ Beckurts and Træger, Arch. der Pharm. 236 (1898), 397.

⁵⁾ Pavesi, Estratto dall' Annuario della Soc. Chimica di Milano 11 (1904), 3; Estratto dai "Rendiconti" del R. Ist. Lomb. di sc. e lett. (II.) 37 (1904), 487; Report of Schimmel & Co. October 1904, 9.

⁶⁾ Alpers, Americ. Journ. Pharm. 71 (1899), 370.

⁷⁾ Tardy, Journ. de Pharm. et Chim. VI, 19 (1904), 132.

⁸⁾ Kurbatow, Liebig's Annalen 173 (1874), 4; comp. Schimmel's Bericht April 1899, 7 and Apotheker Ztg. 21 (1906), 987.

| Sesquiterpene from | B. p. | d | n_D | n_D | Remarks |
|--|--|-------------------|----------------------------|-------|---|
| Oil of <i>Carlina acaulis</i> ¹⁾ (Carlinene) | 139 to 141° (20 mm.) | 0,8733 (22,8°) | — | 1,492 | — |
| Cascarilla oil ²⁾ I | 178 to 181° (100 mm.) 255 to 257° (760 mm.) | 0,911 (20°) | $[\alpha]_D^{25}$ 23,49° | | Neither of these sesquiterpenes yielded a solid hydrochloride, bromide or nitrate |
| Cascarilla oil II | 185 to 190° (100 mm.) 260 to 265° (760 mm.) | 0,924 (20°) | $[\alpha]_D^{25}$ 7,36° | | |
| Ceylon Citronella oil ³⁾ (heavy sesquiterpene) | 170 to 172° (16 mm.) 272 to 275° (760 mm.) | 0,912 (15°) | 5° 50' | — | |
| Conima resin oil ⁴⁾ (Conimene) | 264° | — | — | — | Crystalline derivatives were not obtained |
| Cryptomeria nit ⁵⁾ (Suginene) | | 0,918 | $[\nu]_D - 10^{\circ} 34'$ | | Ladene also is found in the oil. Suginene produces liquid addition products with 2 mol. of hydrohalogen |
| Cuhea oil ⁶⁾ | 262 to 263° | | lavogyrate | | The sesquiterpene fraction consists chiefly of ladene |
| Oil from <i>Eucalyptus haemastoma</i> , also from several other eucalyptus oils ⁷⁾ (Aromadendrene) | 260 to 265° (14°) | 0,9249 (14°) | — | | |
| Fire weed oil ⁸⁾ | 240 to 310° | — | — | — | Adds 1 mol. of hydrogen chloride |

¹⁾ Semmler, Chem. Ztg. 13 (1889), 1158.²⁾ Thoms, Apotheker Ztg. 14 (1899), 562; Fendler, Arch. der Pharm. 238 (1900), 688.³⁾ Schimmel's Bericht October 1899, 19.⁴⁾ Stenhouse and Groves, Liebig's Annalen 180 (1876), 253; Journ. chem. Soc. 25 (1876), 175.⁵⁾ Kinura, Berichte d. deutsch. pharm. Ges. 19 (1909), 369.⁶⁾ Wallach, Liebig's Annalen 234 (1887), 18.⁷⁾ H. G. Smith, Journ. and Proceed. Royal Soc. of N. S. W. 35 (1901); Report of Schimmel & Co. April 1902, 41.⁸⁾ Beilstein and Wiegand, Berl. Berichte 15 (1882), 2854.

| Sesquiterpene from | B. p. | d | n_D | n_D | Remarks |
|--|------------------------|---------------------------|-------------------|-----------------|---|
| Galangal oil ¹⁾ | 230 to 240° | 0,932 (20°) | 27° 12' | 1,4922 | With hydrogen chloride it yields a dihydrochloride melting at 51° |
| Gurjun balsam oil ²⁾ (Gurjunene) | 115 to 118° (7 mm.) | 0,9207 0,9247 (15°) | to up to -130° | 35° (20°) | Crystalline derivatives were not obtained. |
| Hemp oil ³⁾ (Cannabene) | 256 to 258° | 0,9289 (0°) | $[\alpha]_D$ | 10,81° | With hydrogen chloride a solid hydrochloride results. |
| Hemp resin oil ⁴⁾ | 258 to 260 | 0,898 (18°) | $[\alpha]_D$ | 8,6° | |
| Kessio root oil ⁵⁾ | 260 to 280° | — | — | — | A solid hydrochloride could not be obtained. |
| Laurel herry oil ⁶⁾ | abt. 250° | 0,925 (15°) | — | -7,227° | |
| Lavender oil ⁷⁾ | 130° (15 mm.) | — | — | — | |
| Oil from <i>Leptospermum diversifolium</i> ⁸⁾ | | 0,9024 (15°) | | 1,5052 (16°) | |
| Linaloe oil ⁹⁾ , Mexican | 130 to 140° (10 mm) | | | | Adds four atoms of bromine. |
| Oil from <i>Nardostachys jatamansi</i> ¹⁰⁾ | 250 to 254° | 0,932 (15°) | | | |

¹⁾ Schindelneiser, Chem. Ztg. 26 (1902), 308.

²⁾ Unpublished observation made in the laboratory of Schimmel & Co.

³⁾ Valentini, Gazz. chim. ital. 10 (1880), 479 and 11 (1881), 191; Berl. Berichte 13 (1880), 2431 and 14 (1881), 1717.

⁴⁾ Wood, Spivey and Easterfield, Journ. chem. Soc. 60 (1896), 539.

⁵⁾ Bertram and Gildemeister, Arch. der Pharm. 228 (1890), 486.

⁶⁾ Blas, Liebig's Annalen 134 (1865), 1.

⁷⁾ Semmler and Tiemann, Berl. Berichte 25 (1892), 1187.

⁸⁾ Baker and Smith, Journ. and Proceed. Royal Soc. of N. S. W. 1906; Report of Schimmel & Co. October 1906, 46.

⁹⁾ Barbier and Bouveault, Compt. rend. 121 (1895), 168.

¹⁰⁾ Y. Asahina, Journ. pharm. Soc. of Japan 1907, 355; Report of Schimmel & Co. October 1907, 65.

| Sesquiterpene from | B. p. | d | n_D | n_D | Remarks |
|---|---|-----------------|-----------|-----------------|--|
| Patchouli oil ¹⁾ | | | | | |
| I. Sesquiterpene | 264 to 265° (760 mm.) 59 to 96° (3 to 4 mm.) | 0.9335 (15°) | — 58° 45' | — | |
| II. Sesquiterpene | 273 to 274° (15°) | 0.930 (15°) | + 0° 45' | — | — |
| Oil from <i>Pittosporum undulatum</i> ²⁾ | 263 to 274° (15°) | 0.910 (15°) | ± 0° | 1.5030 (20°) | — |
| Sage oil ³⁾ | 264 to 270° (24°) | 0.9072 (24°) | 3° 14' | — | — |
| Sandarach resin oil ⁴⁾ | 260 to 280° (15°) | 0.9386 (15°) | — | 1.5215 | No crystalline derivatives could be obtained with hydrogen chloride, nitrosyl chloride and nitrogen oxide. |
| Valerian oil ⁵⁾ | 160 to 165° (50 mm.) | — | 9.2° | — | — |
| Vetiver oil ⁶⁾ (Vetivene) | 262 to 263° (740 mm.) 135° (12 mm.) | 0.932 (20°) | 18° 19' | — | Adds 4 atoms of bromine. |
| Winters bark oil ⁷⁾ (Winterene) | 260 to 270° (265°) | 0.9344 (13°) | 11.2° | — | The hydrochloride is liquid. |
| Oil of European Wormseed ⁸⁾ | 255° | 0.9170 | — | — | — |

¹⁾ von Soden and Rojahn, Berl. Berichte 37 (1904), 3353.²⁾ Power and Tutin, Journ. chem. Soc. 89 (1906), 1083.³⁾ Sugiyura and Muir, Pharmaceutical Journ. III. 8 (1877), 191, 994; Journ. chem. Soc. 1877, II. 548; Journ. chem. Soc. 37 (1880), 678.⁴⁾ Henry, Journ. chem. Soc. 79 (1901), 1149.⁵⁾ Oliviero, Compt. rend. 117 (1893), 1096; Bull. Soc. chim. III. 11 (1894), 150; 13 (1895), 917.⁶⁾ Genvesse and Langlois, Compt. rend. 135 (1902), 1059.⁷⁾ Arata and Canzonari, *Anales de la Sociedad Científica Argentina*. According to Arch. der Pharm. 227 (1889), 813.⁸⁾ Report of Schimmel & Co. October 1906, 69.

Of the artificially prepared sesquiterpenes that have not been identified with any of the well characterized ones, the following may be mentioned:

| Sesquiterpene | B. p. | d | n _D | n _D | Remarks |
|---|--------------------------------------|-------------------------------------|----------------------------|-------------------|---|
| Caryophyllene dichlorhydrate of the m. p. 69 to 70 °) | | 0,9191 (20 °) | 35,39 ° | 1,49801 | |
| Cedrol ¹⁾ (Cedar camphor resp. cypress camphor) | 263,5 to 264 ° | 0,9367 (15 °) | — 85° 57' | 1,49798 (20 °) | A small yield of nitrosochloride, m. p. 100 to 102 °, was obtained |
| Cubeb camphor ²⁾ | | | | | This sesquiterpene is said to possess constants similar to those of the hydrocarbon found with cadimene in oil of cubeb |
| Sesquiterpene alcohol from <i>Eucalyptus Globulus</i> ³⁾ | 102 to 103 ° | | | | |
| I. Sesquiterpene | (6 mm.) 247 to 248 ° (748 mm.) | 0,8956 (15 °) | — 55° 48' | 1,49287 (20 °) | — |
| II. Sesquiterpene | 265,5 to 266 ° (750 mm.) | 0,9236 (15 °) | — 58° 40' | 1,50602 (20 °) | |
| Gonystylol ⁴⁾ | 137 to 139 ° (17 mm.) | 0,9183 (17 °) | — 40 | | Mol. refr. found 60,7 |
| Ledum camphor ⁵⁾ (Ledol) | 264 ° (752 mm.) | 0,9349 (0 °) 0,9237 (19 °) | — | — | |
| Maali alcohol ⁶⁾ | 270,8 to 271 ° (754 mm.) | 0,9190 (15 °) | [α] _D + 131,99° | 1,52252 (20 °) | Mol. refr. found 67,98. |
| Patchouli alcohol ⁷⁾ | 255 to 256 ° (15 °) | 0,9334 (15 °) | — 36° 52' | — | — |

¹⁾ Schreiner and Kremers, The Sesquiterpenes, Milwaukee 1904, p. 108.

²⁾ Report of Schimmel & Co. October 1904, 24 and April 1910, 46.

³⁾ E. Schmidt, Berl. Berichte 10 (1877), 188.

⁴⁾ Report of Schimmel & Co. April 1904, 52.

⁵⁾ Eyken, Recueil des trav. chim. des P.-B. 25 (1906), 44. According to Chem. Zentralbl. 1906, I. 842.

⁶⁾ Rizza, Journ. russ. phys. chem. Ges. 1887, 319; Berl. Berichte 20 (1887), Ref. 562.

⁷⁾ Report of Schimmel & Co. November 1906, 139.

⁸⁾ Report of Schimmel & Co. April 1904, 69.

Sesquiterpenes that have not yet been further characterized have been found in the volatile oil of *Blumea balsamifera*, in the oils of basilicum, cajeput, *Abies alba*, fennel, hemlock needles, laurel leaves, wild thyme, and milfoil.

ALCOHOLS.

ALIPHATIC ALCOHOLS.

Of the monatomic alcohols of the saturated or methane series but few representatives have thus far been found in volatile oils. In the free state they are found but rarely and then only the lower homologues; more commonly, however, combined with fatty acids. The occurrence of both free alcohol and free acid may in most instances be attributed to the saponification of esters during the process of distillation. If the material to be distilled contains carbohydrates, it may occur that the presence of free alcohols is due to fermentation previous to the distillation. Thus, e. g. ethyl alcohol has been observed in the distillate of rose petals that had been bulked for a short time only.

The methods of preparation of these alcohols are those commonly in vogue. In factory practice, volatile oils containing esters, particularly of the higher members, are used as first materials. Very serviceable is also the method of Bouveault and Blanc,¹⁾ according to which primary alcohols are obtained upon reduction of the esters of the respective acids by means of sodium and alcohol.

With the increase in the number of carbon atoms, the properties of the aliphatic alcohols undergo material change. Hence, so far as seemed necessary, attention is directed thereto.

The individual alcohols can be identified by means of their constants, also by their oxidation products. As specially charac-

¹⁾ G. I. P. 164294. Comp. also Compt. rend. 136 (1903), 1676; 137 (1903), 60.

teristic derivatives, the phenylurethanes should be mentioned. These are obtained by mixing equimolecular parts of phenyl/isocyanate and the alcohol in question. Upon standing of the mixture, the urethane separates in crystalline form.

Methyl alcohol, CH_3OH , occurs frequently among the products of distillation of plant material with water vapors. On account of its ready solubility in water it is frequently found in the aqueous distillate only, together with furfural and diacetyl. It is assumed that these three substances result as decomposition products of the cellulose of the crude material during the process of distillation. Up to the present time, methyl alcohol has been found in the aqueous distillate of the oils of cypress, savin, vetiver, and orris, of the oils from the leaves of *Indigofera galeoides*, the leaves from the Guatamala indigo plant, coca leaves, sappan leaves, also in the aqueous distillates from the West-Indian sandalwood oil, tea oil, oil of cloves, oil of *Eucalyptus amygdalina*, bay oil, pastinaca oil, garden chervil oil, the oils of *Heracleum Sphondylium*, and *H. giganteum*, also of ageratum oil. In addition it has been found as myristic ester in orris oil, as benzoic ester in the oils of tuberose (?) and ylang-ylang, as cinnamic ester in the oil from the root of *Alpinia malaccensis* and watara oil, as salicylic ester in the oil from tuberose pomade, birch bark oil, cananga oil, oil of rue, oil of cassie flowers, tea oil and wintergreen oil, as ester of methyl anthranilic acid in mandarin oil and as anthranilic ester in the oils of neroli and jasmin.

Methyl alcohol can be identified by its boiling point 64° , its density 0.810 at 15° and chemically by its conversion into methyl iodide and neutral oxalate which melts at 54° .

Ethyl alcohol, $\text{C}_2\text{H}_5\text{OH}$. As normal constituent of volatile oils, ethyl alcohol has been observed only in a few instances: thus in the first fraction of the oils of *Indigofera* and of the fruit of *Morinda citrifolia*, also in the aqueous distillate of *Eucalyptus amygdalina*, of chevril oil, pastinaca, and *Heracleum giganteum*. Its occurrence in the distillate of rose petals that have undergone fermentation has already been mentioned. As ester it occurs as butyrate in the oils of *Heracleum Sphondylium*

and *H. giganteum*, as capric acid in cognac oil, and as cinnamate in storax oil and k  mpferia oil.

As one of the most common adulterants of volatile oils, alcohol plays an important role.

It is identified by means of its constants (b. p. 78 ; d_{15} , 0.794) also by its conversion into either ethyl iodide or iodoform.

n-Butyl alcohol, $\text{CH}_3(\text{CH}_2)_3\text{CH}_2\text{OH}$, occurs as ester in Roman chamomile oil. At 20° its density is 0.810 and it boils at 117°. Its phenyl urethane melts between 55 and 56°.)

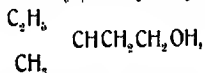
Isobutyl alcohol, $\begin{array}{c} \text{CH}_3 \\ | \\ \text{CHCH}_2\text{OH} \end{array}$, is contained, according to H. G. Smith, in the aqueous distillate of *Eucalyptus amygdalina*. It boils at 108.4° ; sp. gr. 0.8003 at 18°. Its phenyl urethane melts at 80°.)

Isoamyl alcohol, $\begin{array}{c} \text{CH}_3 \\ | \\ \text{CHCH}_2\text{CH}_2\text{OH} \end{array}$, occurs as such in the oils of *Eucalyptus Globulus*, *E. amygdalina*, in geranium oil from R  union,*) lavender oil and French peppermint oil. As ester it occurs in the oils of *Eucalyptus Globulus*, *E. aggregata*, in Roman chamomile oil and in cognac oil.

It is readily recognized by its irritating odor, boiling point 131° ; its phenyl urethane melting at 52 to 53° and by its oxidation to isovaleric aldehyde and isovaleric acid.

n-Hexyl alcohol, $\text{CH}_3(\text{CH}_2)_5\text{CH}_2\text{OH}$, occurs as ester in the oil of male fern and in the oils of *Heracleum Sphondylium* and *H. giganteum*. It boils at 157° and has a specific gravity of 0.8204 at 20°. Upon oxidation it yields capronic acid b. p. 205°.

Active hexyl alcohol (*i,i*-methyl ethyl propyl alcohol)



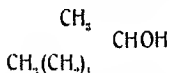
occurs as ester of angelic acid in Roman chamomile oil. It is

*) Blaise, Bull. Soc. chim. III. 29 (1903), 327.

*) It has not been definitely established whether this is the common isoamyl alcohol or not.

dextrogyrate, $[\alpha]_D^{20}$: 8,2 ; d_{16}^{20} 0,829 ; b. p. 154 . Chromic acid mixture oxidizes it to active capronic acid boiling between 196 to 198°.

Heptyl alcohol. Of the heptyl alcohols, the *methyl-n-amyl carbinol*,



has been found in oil of cloves by Masson.¹⁾ He enumerates the following constants: b. p. 157 to 158 ; d_{16}^{20} 0,8344. Upon oxidation with chromic acid mixture it is converted into methyl-n-amyl ketone, the semicarbazone of which melts at 122 to 123 and can be used for identification purposes. For this the pyro-nvic acid ester is likewise suited, the semicarbazone of which melts at 118 to 119°.

n-Octyl alcohol, $\text{CH}_3(\text{CH}_2)_6\text{CH}_2\text{OH}$, probably occurs in the free state in the oils of *Heracleum Sphondylium* and *H. giganteum*, in which it also occurs as acetate. As propionate (?) it has been found in pastinaca oil, as butyrate in male fern and pastinaca oils, as isovalerate in male fern oil, as capronate, capriate and laurinate in the oil of *H. Sphondylium*.

It is identified by means of its constants (b. p. 196 to 197° ; d_{16}^{20} 0,8278), also by its oxidation to octylic aldehyde (the β -naphtho-cinchoninic acid of which melts at 234°), or to caprylic acid (m. p. 16,5° and b. p. 232 to 234°).

n-Nonyl alcohol, $\text{C}_{11}\text{H}_{23}\text{O}$, $\text{CH}_3(\text{CH}_2)_8\text{CH}_2\text{OH}$, has been found as ester of caprylic acid in sweet orange oil. Under ordinary pressure it boils at 213,5° and has a rose-like odor somewhat resembling that of citronellol. For the alcohol, purified through the phthalic ester, Stephan²⁾ records the following properties:

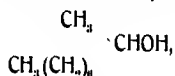
B. p. 98 to 101 (12 mm.); d_{16}^{20} 0,840; n_D^{20} 1,43582.

Nonyl alcohol can be identified by means of its oxidation products (nonyl aldehyde and pelargonic acid, m. p. 12,5°), also by means of its phenylurethane which melts at 62 to 64°.

¹⁾ Compt. rend. 149 (1909), 630.

²⁾ Journ. f. prakt. Chem. II. 62 (1900) 532.

As secondary nonyl alcohol, *methyl-n-heptylcarbinol*,

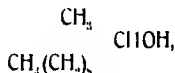


has been found by Power and Lecs¹⁾ in an Algerian oil of rue, and by Masson²⁾ in clove oil. Its properties are recorded as follows:

B. p. 198 to 200 (765 mm.); d_{20}^{20} 0.8273; n_D^{20} (50 mm.) — 33.44' (Power and Lecs); b. p. 195 to 196'; d_4 0.8399 (Masson).

It can be identified by its oxidation product, methyl-*n*-heptylketone and the semicarbazone of the latter (m. p. 118 to 119). With pyruvic acid it forms an ester which boils at 126 to 127' (16 mm.), and the semicarbazone of which melts at 117.

Undecyl alcohol. A secondary undecyl alcohol, methyl-*n*-nonyl-carbinol



has also been found in the Algerian oil of rue mentioned above. For the purified alcohol, Power and Lecs record the following constants:

B. p. 231 to 233; n_D^{20} (25 mm.) — 1 18'.

It is identified by means of its oxidation product, the methyl-*n*-nonyl ketone, the oxime of which melts at 46', the semicarbazone at 123 to 124.

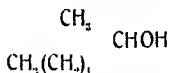
Of unsaturated aliphatic alcohols the hexylene alcohol $\text{C}_6\text{H}_{12}\text{O}$ which occurs in the tea leaf oil, and the alcohol $\text{C}_8\text{H}_{16}\text{O}$, probably an octylene alcohol, which occurs in Gaultheria oil, may be mentioned as representatives of the lower members of the series. Of much greater interest, however, are the terpene alcohols $\text{C}_{10}\text{H}_{18}\text{O}$, linalool, geraniol, and nerol; furthermore, the unsaturated chain alcohol $\text{C}_{10}\text{H}_{20}\text{O}$, citronellol. These occur as such and as esters in volatile oils of which they are important constituents because of their fragrance.

¹⁾ Journ. chem. Soc. 81 (1902), 1592.

²⁾ Compt. rend. 149 (1909), 630.

dextrogyrate, $[\alpha]_D^{20}$: 8,2 ; d_{16}^{20} 0,829 ; b. p. 154 . Chromic acid mixture oxidizes it to active capronic acid boiling between 196 to 198°.

Heptyl alcohol. Of the heptyl alcohols, the *methyl-n-amyl carbinol*,



has been found in oil of cloves by Masson.¹⁾ He enumerates the following constants: b. p. 157 to 158 ; d_{16}^{20} 0,8344. Upon oxidation with chromic acid mixture it is converted into methyl-n-amyl ketone, the semicarbazone of which melts at 122 to 123 and can be used for identification purposes. For this the pyro-nvic acid ester is likewise suited, the semicarbazone of which melts at 118 to 119°.

n-Octyl alcohol, $\text{CH}_3(\text{CH}_2)_6\text{CH}_2\text{OH}$, probably occurs in the free state in the oils of *Heracleum Sphondylium* and *H. giganteum*, in which it also occurs as acetate. As propionate (?) it has been found in pastinaca oil, as butyrate in male fern and pastinaca oils, as isovalerate in male fern oil, as capronate, capriate and laurinate in the oil of *H. Sphondylium*.

It is identified by means of its constants (b. p. 196 to 197° ; d_{16}^{20} 0,8278), also by its oxidation to octylic aldehyde (the β -naphtho-cinchoninic acid of which melts at 234°), or to caprylic acid (m. p. 16,5° and b. p. 232 to 234°).

n-Nonyl alcohol, $\text{C}_{11}\text{H}_{23}\text{O}$, $\text{CH}_3(\text{CH}_2)_8\text{CH}_2\text{OH}$, has been found as ester of caprylic acid in sweet orange oil. Under ordinary pressure it boils at 213,5° and has a rose-like odor somewhat resembling that of citronellol. For the alcohol, purified through the phthalic ester, Stephan²⁾ records the following properties:

B. p. 98 to 101 (12 mm.); d_{16}^{20} 0,840; n_D^{20} 1,43582.

Nonyl alcohol can be identified by means of its oxidation products (nonyl aldehyde and pelargonic acid, m. p. 12,5°), also by means of its phenylurethane which melts at 62 to 64°.

¹⁾ Compt. rend. 149 (1909), 630.

²⁾ Journ. f. prakt. Chem. II. 62 (1900) 532.

fractionation of the oil which has previously been saponified. As a result, the constants recorded for linalool apply to products thus obtained. If it is desired to free the alcohol from indifferent substances, such as the terpenes, it can be converted into the sodium salt of the acid phthalic ester according to Tiemann's method¹⁾ by allowing phthalic acid anhydride to act on sodium linalool. The sodium salt of this acid phthalic ester of linalool is soluble in water and can be saponified with alcoholic potassa. In as much as linalool is subject to changes when distilled from an alkaline solution with water vapor²⁾ -- changes that are indicated by a reduction in the optical rotation -- the regenerated alcohol must be shaken out of the alcoholic-alkaline solution by means of ether.

According to the nature of the crude material, also according to the method of preparation, products have been obtained that varied slightly in their properties. In judging the purity of a product the following data may be used for comparison.

b. p. 197 to 199°, 85 to 87 (10 mm.); d_{15}^4 0,870 to 0,875; n_{15}^{20} 1,4630 to 1,4690.³⁾

b. p. 86 to 87° (14 mm.); d_{20}^4 0,8622 (?); n_D^{15} 1,46108.⁴⁾

b. p. 198 to 199° (760 mm.), 88,3 to 89,5 (13 mm.); d_{15}^4 0,870; n_{15}^{20} 1,4668.⁵⁾

In connection with technical products obtained in the laboratory of Schimmel & Co., the following constants have been observed:

b. p. 197 to 199°, 69 to 71 (4 mm.); d_{15}^4 0,869 to 0,873; α_D^{20} -3° to -17°, resp. +9° to -13°; n_{15}^{20} 1,462 to 1,464; soluble in 10 to 15 vols. of 50 p. c. alcohol, in 4 to 5 vols. of 60 p. c. and 1 to 2 vols. of 70 p. c. alcohol.

The angle of rotation is not fixed, the highest thus far observed is that for *l*-linalool from limette oil $[\alpha]_D^{20}$ -20° 7',³⁾ for

¹⁾ Berl. Berichte 31 (1898), 837.

²⁾ These changes appear to be of a chemical nature and not due merely to inversion. The angle of rotation of *l*-linalool is not altered by boiling with potassium hydroxide. Charabot, Bull. Soc. chim. III. 21 (1899), 549.

³⁾ Stephan, Journ. f. prakt. Chem. II. 58 (1898), 110.

⁴⁾ Tiemann, Berl. Berichte 31 (1898), 834.

⁵⁾ Gildemeister, Arch. der Pharm. 233 (1895), 179.

d-linalool from sweet orange oil [n_D^{20} , 1.4918¹⁾]. In most instances, and more particularly in specimens with a low angle of rotation, the products are, no doubt, mixtures of both optical modifications, in which one or the other predominates.

Artificially linalool can be obtained, though in the inactive modification only, when geraniol is heated with water to 200° in an autoclave;²⁾ or by the action of hydrogen chloride on geraniol and subsequent treatment of the linalyl chloride thus obtained with alcoholic potassa or silver nitrate.³⁾ As to its formation from geranylphthalate of sodium see p. 361.

As an unsaturated alcohol with two double bonds, linalool reveals additive capacity. It combines with bromine, also with hydrohalogen to compounds which, with the exception of linalyl chloride,⁴⁾ $C_{10}H_{17}Cl$ (b. p. 95 to 96° at 6 mm.), have been investigated but little.

The unsaturated tertiary character of the alcohol is revealed by its behaviour towards reagents. Whereas alkalis act on it but little in the cold, organic acids convert it either into geraniol, nerol, or — in the presence of a little sulphuric acid — into terpineol. Mineral acids change it to cyclic compounds, the change being accompanied either by the abstraction of water or the addition of water. Thus, when shaken with a 5 p. c. sulphuric acid, terpin hydrate is formed;⁵⁾ when heated with glacial acetic acid and acetic anhydride, there are formed geranyl acetate, the acetate of the solid terpineol⁶⁾ with an optical rotation opposite to that of the linalool used as starting point, also neryl-acetate.⁷⁾ Formic acid at room temperature (20°) converts it into its own formate, also into the formate of the solid terpineol with opposite rotation. However, when gently heated (60 to 70°) formic acid dehydrates it, yielding the hydrocarbons dipentene and terpinene.⁸⁾

¹⁾ Stephan, Journ. f. prakt. Chem. II. 62 (1900), 529.

²⁾ Report of Schimmel & Co. April 1898, 27.

³⁾ Tiemann, Berl. Berichte 31 (1898), 832; Berichte von Roure-Bertrand Fils October 1900, 27.

⁴⁾ Dupont and Lahaune, Berichte von Roure-Bertrand Fils October 1900, 21.

⁵⁾ Tiemann and Schmidt, Berl. Berichte 28 (1895), 2137.

⁶⁾ Stephan, Journ. f. prakt. Chem. II. 58 (1898), 109.

⁷⁾ Zeitschel, Berl. Berichte 39 (1906), 1780.

⁸⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 45 (1892), 601.

fractionation of the oil which has previously been saponified. As a result, the constants recorded for linalool apply to products thus obtained. If it is desired to free the alcohol from indifferent substances, such as the terpenes, it can be converted into the sodium salt of the acid phthalic ester according to Tiemann's method¹⁾ by allowing phthalic acid anhydride to act on sodium linalool. The sodium salt of this acid phthalic ester of linalool is soluble in water and can be saponified with alcoholic potassa. In as much as linalool is subject to changes when distilled from an alkaline solution with water vapor²⁾ -- changes that are indicated by a reduction in the optical rotation -- the regenerated alcohol must be shaken out of the alcoholic-alkaline solution by means of ether.

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²⁾ These changes appear to be of a chemical nature and not due merely to inversion. The angle of rotation of *l*-linalool is not altered by boiling with potassium hydroxide. Charabot, Bull. Soc. chim. III. 21 (1899), 549.

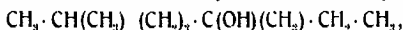
³⁾ Stephan, Journ. f. prakt. Chem. II. 58 (1898), 110.

⁴⁾ Tiemann, Berl. Berichte 31 (1898), 834.

⁵⁾ Gildemeister, Arch. der Pharm. 233 (1895), 179.

derivative, or is treated with metallic sodium in alcoholic solution, or when it is heated to 220 to 230° with zinc dust.¹⁾ The sodium derivative of linalool is readily soluble in an excess of linalool and can be utilized for preparing this alcohol in a pure state.

When reducing linalool with nickel and hydrogen, Enklaar²⁾ obtained, in addition to 2,6-dimethyloctane, 2,6-dimethyloctanol-6,

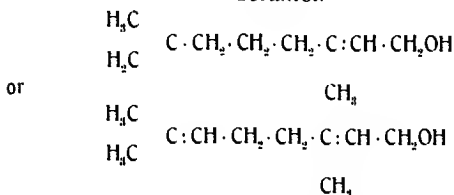


thus supporting the correctness of the formula of Tiemann and Semmler given above.

The esters of linalool, so far as those occurring in volatile oils are concerned, are liquids with a more or less strong and agreeable odor, which cannot be distilled without decomposition under ordinary pressure. The synthetic preparation of these esters, however, is coupled with difficulties since linalool is rather susceptible toward acids. Hence, when linalool is boiled with acid anhydrides or when treated in accordance with the G. I. P. 80711, the products which result consist in the main of esters of linalool, but also contain those of geraniol and terpinol.

Compounds suited to the identification of linalool are the phenylurethane, melting at 65 to 66°, and the α -naphthylurethane melting at 53°. For its further identification it can be oxidized to citral and this characterized by the citral-*l*-naphthocinchonic acid discovered by Doebner. If citronellal be present with citral, both are first separated by means of their acid sulphite addition products.

Geraniol.



Isomeric with linalool is geraniol $\text{C}_{10}\text{H}_{18}\text{O}$ which is distinguished from the former by its optical inactivity, higher boiling

¹⁾ Semmler, Berl. Berichte 27 (1894), 2520.

²⁾ Berl. Berichte 41 (1908), 2083; Recueil des trav. chim. des P.-B. 27 (1908), 411; Chem. Zentralbl. 1908, II, 1926.

point and higher specific gravity. It is the "lemonol" of Barbier and Bouveault, the "rhodinol" of Erdmann and Huth and of Poleek. Both as such and as ester it is found rather frequently in volatile oils. It constitutes the bulk of palmarosa oil, of German and Turkish rose oils, and is found in appreciable quantities in the oils of geranium, citronella and lemongrass. It has further been found in the oils of gingergrass, Canada snakeroot, ylang-ylang, champaca flowers, nutmeg, sassafras leaves, laurel leaves, kuro-moji, tetranthera (?), cassie flowers (from *Acacia Cavenia* and *A. Farnesiana*), neroli, petitgrain, coriander, Mexican and Cayenne lignaloe, of *Darwinia fascicularis* (?), *Eucalyptus Macarthuri*, *E. Staigeriana*, *Leptospermum Livsidsgei*, verbena, spike (?) and lavender. As acetate it occurs in the needle oil of *Callitris glauca*, the oils of palmarosa, lemongrass, sassafras leaves, kuro-moji, lemon, petitgrain, *Eucalyptus Macarthuri*, *E. Staigeriana*, *Leptospermum Livsidsgei*, *Darwinia fascicularis* and lavender; as isovalerianate in sassafras leaf oil; as *n*-capronate in palmarosa and lavender oils; and as tiglate in geranium oil.

As a primary alcohol, geraniol forms a crystalline addition product with calcium chloride,¹⁾ which is insoluble in ether, ligroin, benzene and chloroform, and which is resolved into its components by water. By this extremely simple method, geraniol can be obtained chemically pure (see below). With magnesium chloride, calcium nitrate and magnesium nitrate, crystalline derivatives are likewise formed.²⁾

For the isolation of geraniol from mixtures with hydrocarbons and other substances a number of other methods have been suggested. All of them have this in common that they aim at the preparation of an acid phthalate of geraniol. This ester can be prepared either by the action of phthalic acid anhydride on the sodium compound of crude geraniol,³⁾ or by heating geraniol with phthalic acid anhydride without solvent in the water bath⁴⁾ or in benzene solution.⁵⁾ The ester can be purified through the

¹⁾ Jacobsen, Liebig's Annalen 157 (1871), 234.

²⁾ Report of Schimmel & Co. April 1896, 44.

³⁾ Tiemann and Krüger, Berl. Berichte 29 (1896), 901.

⁴⁾ H. and E. Erdmann, Journ. f. prakt. Chem. II. 56 (1897), 15.

⁵⁾ Flatau and Labbé, Compt. rend. 126 (1898), 1725; Bull. Soc. chim. III. 19 (1898), 633; Stephan, Journ. f. prakt. Chem. II. 60 (1899), 248.

crystalline silver salt. The geraniol is regenerated by saponifying either the acid ester, or its sodium salt, the latter being prepared from the silver salt. These methods, however, do not possess any advantages over the calcium chloride method. Indeed, they are more complicated and yield no purer product.

Purified geraniol, prepared by one or the other of the above mentioned methods, is a colorless, oily liquid with a rose-like odor which is optically inactive. When exposed to the air it is modified, taking up oxygen and suffering in its fragrance. Its properties are recorded as follows:

B. p. 110 to 111 (10 mm.), 121 (18 mm.), 230 (under atmospheric pressure).¹⁾

B. p. 120,5 to 122,5 (17 mm.); d_{20}^4 0,8894 (!); n_{D20}^{20} 1,4766.²⁾

B. p. 110,5 to 111 (corr., at 10 mm.); d_4^{16} 0,8812.³⁾

d_{12}^4 0,880 to 0,883; n_{D12}^{12} 1,4766 to 1,4786.¹⁾

In connection with products prepared by themselves on a large scale Schimmel & Co. observed the following properties:

B. p. 229 to 230 (757 mm.), 114 to 115 (12 mm.); d_{12}^4 0,883 to 0,886; n_{D12}^{12} 1,476 to 1,478; soluble in 8 to 15 vols. of 50 p. c. alcohol and in 2,5 to 3,5 vols. of 60 p. c. alcohol.

Upon oxidation geraniol, as primary alcohol, yields citral, from which it can again be obtained by reduction.⁴⁾ In as much as citral has been obtained synthetically, geraniol also belongs to those substances that can thus be obtained.

Upon application of Sabatier and Senderens'⁵⁾ method, Bonneault⁶⁾ succeeded in converting geraniol well nigh quantitatively into citral. This method consists in the catalytic action of copper on primary alcohols at high temperature.

Geraniol, or rather its acetate, results together with terpineol and nerol, when linalool is heated for a long time with acetic

¹⁾ Bertram and Gildemeister, Journ. f. prakt. Chem. II. 56 (1897), 508.

²⁾ Tiemann and Semmler, Berl. Berichte 26 (1893), 2711.

³⁾ H. and L. Erdmann, Journ. f. prakt. Chem. II. 56 (1897), 3; Berl. Berichte 31 (1898), 359, Ann. 1.

⁴⁾ Stephan, Journ. f. prakt. Chem. II. 54 (1898), 110; 60 (1899), 244.

⁵⁾ Tiemann, Berl. Berichte 31 (1898), 828.

⁶⁾ Compt. rend. 136 (1903), 738, 921, 983.

⁷⁾ Bull. Soc. chim. IV. 3 (1908), 119.

acid anhydride.¹⁾ The reverse reaction takes place when geraniol is heated with water to 200° in an autoclave. At higher temperatures hydrocarbons and their polymerization products are formed.²⁾ When hydrogen chloride is allowed to act on a mixture of geraniol and toluene, linalyl chloride results which, with silver nitrate, yields linalool.³⁾ Hence it can be explained how Tiemann⁴⁾ could obtain linalool when treating geraniol with hydrogen chloride and saponifying the reaction product with alcoholic potassa.

In general, geraniol is not as readily acted upon by acids as is linalool. However, the action of acid reagents may cause ring formation, cyclogeraniol being produced. When boiled with acetic acid anhydride it is quantitatively converted into the acetate, but not isomerized. When shaken with dilute sulphuric acid it is converted into terpinhydrate, as is linalool, but not as readily.⁵⁾ Concentrated formic acid, like potassium acid sulphate or phosphoric acid, acts as dehydrating agent. Whereas the action of potassium acid sulphate is said to produce an open chain hydrocarbon,⁶⁾ the other reagents produce terpenes. Thus formic acid produces α -terpineol, dipentene and terpinene.⁷⁾ Upon reduction of geraniol with platinum sponge and hydrogen, Willstätter and Mayer⁸⁾ obtained a mixture of 2,6-dimethyl octane and 2,6-dimethyloctanol-8. The same products were obtained by Enklaar⁹⁾ with Sabatier's method. In addition, however, there resulted a cyclic alcohol $C_{10}H_{20}O$ not further characterized.

In the cold geraniol is scarcely acted upon by alkalis. When heated with concentrated alcoholic potassa to 150°, there is formed, according to Barbier,¹⁰⁾ a tertiary alcohol $C_{10}H_{18}O$

¹⁾ Bouchardat, *Compt. rend.* 116 (1893), 1253; Tiemann and Semmler, *Berl. Berichte* 26 (1893), 2714; Stephan, *Journ. f. prakt. Chem.* II. 58 (1898), 111.

²⁾ Report of Schimmel & Co. April 1908, 27.

³⁾ Tiemann, *Berl. Berichte* 31 (1898), 832; Dupont and Labaune, *Berichte von Roure-Bertrand Fils* October 1900, 27.

⁴⁾ Tiemann and Schmidt, *Berl. Berichte* 28 (1895), 2138.

⁵⁾ Semmler, *Berl. Berichte* 24 (1891), 683.

⁶⁾ Bertram and Gildemeister, *Journ. f. prakt. Chem.* II. 49 (1894), 195; 53 (1896), 236; Stephan, *Journ. f. prakt. Chem.* II. 60 (1899), 244.

⁷⁾ *Berl. Berichte* 41 (1908), 1475.

⁸⁾ *Ibidem* 2083.

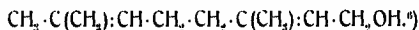
⁹⁾ *Compt. rend.* 126 (1898), 1423.

¹⁰⁾ *Compt. rend.* 126 (1898), 1423.

while carbon dioxide is being split off. However, this statement is based on an error since the resulting alcohol is methyl heptenol $C_{10}H_{18}O$.¹⁾

The addition products of bromine and hydrohalogen are mostly liquid and readily decomposable. However, a crystalline tetrabromide of geraniol, melting at 70 to 71°, can be prepared.²⁾

As already pointed out on p. 358 geraniol yields upon oxidation with chromic acid mixture first an aldehyde, citral, $C_{11}H_{18}O$.³⁾ Under special conditions, however, methylheptenone can also be obtained.⁴⁾ Other "Abbau" products are likewise obtained, so that the reaction is by no means a quantitative one. When shaken with very dilute permanganate solution polyatomic alcohols are presumably first formed. With chromic acid mixture these are oxidized to acetone, levulinic acid and oxalic acid.⁵⁾ In as much as geraniol is optically inactive and a primary alcohol, the above oxidation products have led to the adoption of the following formula, viz., that of dimethyl-2,6-octadiene-2,6-diol-8.



The isomeric formula given above, however, appears to have some points in its favor. Like citronellol, geraniol can add sodium acid sulphite, namely two molecules since it has two double bonds.⁷⁾

The occurrence of esters of geraniol in volatile oils has already been mentioned. In as much as geraniol is relatively stable toward acids, its esters can be obtained either by the action of acid anhydrides on geraniol, or by the action of acid chlorides on geraniol in the presence of pyridine.⁸⁾ The esters of the fatty acids are all liquid and their odor becomes fainter with the increase of the radical of the acid introduced. The formate and the acetate are described among the esters.

¹⁾ Report of Schimmel & Co. October 1898, 27; Tiemann, Berl. Berichte 31 (1898), 2941.

²⁾ v. Soden and Trefft, Berl. Berichte 39 (1906), 913.

³⁾ Semmler, Berl. Berichte 23 (1890), 2965; 24 (1891), 203.

⁴⁾ Semmler, Berl. Berichte 26 (1893), 2720.

⁵⁾ Tiemann and Semmler, Berl. Berichte 28 (1895), 2130.

⁶⁾ *Ibidem* 2132.

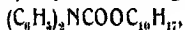
⁷⁾ Labbé, Bull. Soc. chim. III. 21 (1898), 1079.

⁸⁾ H. and E. Erdmann, Journ. f. prakt. Chem. II. 56 (1897), 14; Berl. Berichte 31 (1898), 356.

Of the other esters of geraniol the diphenylcarbamino acid ester and the acid phthalic acid ester should be mentioned. Both are crystalline. The former may well be used for the identification of geraniol (see p. 362) whereas the latter (m. p. 47°)¹⁾ may be employed in the preparation of pure geraniol. It should be noted, however, that geranylphthalate of sodium is partly converted into linalool when subjected to distillation with steam.²⁾ A tetrabromide of the geranylphthalic acid is also known which melts at 114 to 115°. The silver salt melts at 133°. When preparing this acid it is best to work in benzene solution for the purpose of avoiding higher temperatures, for otherwise the geraniol is completely destroyed. The following derivatives remain to be mentioned, viz., geranyl- α -naphthylurethane (m. p. 47 to 48°), geranyl-di- β -naphthylurethane (m. p. 105 to 107°), and the geranylurethane (m. p. 124°).

For the purpose of separating geraniol from a geraniol-containing oil one can proceed, according to Bertram and Gilde-meister,³⁾ in the following manner: Equal parts of the oil and finely powdered calcium chloride are carefully mixed in a mortar. The mixture, which as a result of the reaction has heated itself to 30 to 40°, is set aside for several hours in a desiccator in a cool place. The solid mass is pulverized and triturated with anhydrous ether, benzene or low boiling petroleum ether, transferred to a force filter and washed with ether, respectively benzene or petroleum ether. To the mixture of geraniol-calcium chloride with the excess of calcium chloride, water is added thus causing the geraniol to be regenerated. The separated oil is washed repeatedly with warm water and finally distilled with steam.

The separation of geraniol from its mixtures according to this method is not quantitative. Moreover, the oil to be thus treated should contain at least 25 percent. of geraniol. If only small amounts of material are available, it is best to use for characterization the diphenylurethane of geraniol



first recommended by Erdmann and Huth.⁴⁾ For its preparation

¹⁾ Flatau and Labbé, *Compt. rend.* 126 (1898), 1725.

²⁾ Stephan, *Journ. f. prakt. Chem.* II. 60 (1899), 252.

³⁾ *Journ. f. prakt. Chem.* II. 53 (1896), 233; 56 (1897), 507.

⁴⁾ *Journ. f. prakt. Chem.* II. 53 (1896), 45.

the following directions are given:¹) 1 g. of oil, 1.5 g. diphenyl-carbamine chloride and 1.35 g. pyridine are heated for two hours on a water bath. The reaction product is subjected to steam distillation and the residue, which solidifies upon cooling, crystallized from alcohol. If much citronellol is present with the geraniol, it is difficult to obtain a pure product, since citronellol yields also a diphenylurethane which, however, remains liquid. In such a case, urethanes with a low melting point (40 to 50°) are first obtained which after repeated recrystallization from alcohol may show the melting point of the diphenylurethane of geraniol, viz., 82.2°.

If geraniol is to be further characterized, it can be oxidized to citral and this converted into the citryl-*l*-naphthocinchonic acid (see Citral). For this purpose, however, the alcohol must be fairly pure and not contain linalool, since this likewise yields citral with chromic acid mixture. If citral is present with geraniol the former must first be removed which removal may be accomplished by treatment with sulphurous acid.

A conversion of geraniol to citronellol is possible through the geranic acid. This is reduced to citronellic acid and the latter to citronellol.²) Thus the proof is established that citronellol is dihydrogeraniol.

Nerol.

This alcohol which is stereoisomeric with geraniol was found in 1902 in neroli oil³) in which it occurs principally as acetate. Furthermore, nerol has been found in the oils of petitgrain, rose, Mexican lignaloes and *Helichrysus angustifolium*. Synthetically it is obtained, together with geraniol and terpineol, by the action of acetic acid anhydride on linalool.⁴) It is likewise obtained in small amount (about 5 p. c.) upon the reduction of citral.

Nerol of unquestioned purity has not yet been obtained. The following constants were observed on a specially purified product: B. p. 226 to 227° (755 mm.); 125° (25 mm.); d_{20}^4 , 0.8813; n_D^{20} , 1.4600.

¹) Journ. f. prakt. Chem. II. 56 (1897), 28.

²) Tiemann, Berl. Berichte 31 (1898), 2839; Bouveault and Gournand, Compt. rend. 138 (1904), 1699.

³) Hesse and Zeitschel, Journ. f. prakt. Chem. II. 66 (1902), 502.

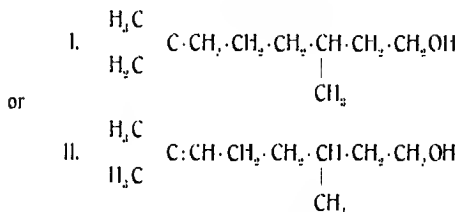
⁴) Zeitschel, Berl. Berichte 39 (1906), 1780.

⁵) v. Soden and Treff, Chem. Ztg. 27 (1903), 897.

Nerol possesses an agreeable, rose-like odor and in its chemical behavior reveals close similarity with geraniol. When shaken with dilute sulphuric acid, it readily yields terpin hydrate. Upon oxidation it yields either citral or an aldehyde that possesses the odor of citral. Like geraniol it is unstable toward formic acid at higher temperature. With calcium chloride it does not form a crystalline addition product, hence it can be separated, at least in part, from geraniol. A like separation may be affected by the diphenylurethanes because of their different solubilities in certain solvents such as petroleum ether and methyl alcohol.

Of its derivatives the tetrabromide¹⁾ melting at 118 to 119 and the diphenylurethane²⁾ melting at 52 to 53 should be mentioned.

Citronellol.



(The rhodinol of Barbier?)

Citronellol, $\text{C}_{10}\text{H}_{20}\text{O}$, was first obtained by Dodge³⁾ by the reduction of citronellal from citronella oil. The citronellol thus prepared like the aldehyde from which it is obtained, is dextrogyrate. In volatile oils citronellol has been found repeatedly. Both optical modifications occur in the geranium oils, *l*-citronellol in oil of rose, and *d*-citronellol in citronella oil from Java and in the oil of *Barosma pulchellum*. Citronellol has also been found in savin oil. Probably its esters as well as the free alcohol occur in volatile oils.

¹⁾ v. Soden and Treff, Berl. Berichte 39 (1906), 907.

²⁾ v. Soden and Treff, Chem. Ztg. 27 (1903), 897; comp. Report of Schimmel & Co. April 1904, 109.

³⁾ Americ. chem. Journ. 11 (1889), 456.

As has been demonstrated, the alcohols described as "rhodinol"¹⁾ and "reuniol"²⁾ revealed themselves as mixtures of citronellol and geraniol. The "roseol" of Markownikoff and Reformatsky,³⁾ that constitutes the bulk of oil of rose, has likewise been found to consist of a mixture of citronellol and geraniol. However, as a result of more recent investigations, Barbier and his colahorers, more particularly Bouveault, insist that the lævogyrate alcohol $C_{10}H_{20}O$ which occurs in pelargonium oil and oil of rose differs from the ordinary *d*-citronellol more than by being merely its lævogyrate modification. Bouveault,⁴⁾ therefore, insists on the retention of the name "rhodinol". Whether this is justified remains to be seen. The work thus far done on this subject by Hesse,⁵⁾ Wallach and Naschold,⁶⁾ Erdmann and Huth,⁷⁾ Bertram and Gildemeister,⁸⁾ Tiemann and Schmidt⁹⁾ has not yet settled the question. This much, however, is demonstrated that rhodinol consists at least in part of citronellol.

According to Bouveault¹⁰⁾ formula I should be assigned to citronellol, formula II to rhodinol. He is lead to this assumption by the different behavior of the corresponding aldehydes (comp. under citronellal).

Of the citronellol, obtained by the reduction of citronellal, Schimmel & Co.¹¹⁾ prepared the pyrouvic ester and the semicarbazone and thus established the identity of the latter derivative with that obtained by Bouveault from "rhodinol". The respective melting points are 110 to 111 and 112.

¹⁾ Eckart, Arch. der Pharm. 229 (1891), 355; Berl. Berichte 24 (1891), 4205; Barbier and Bouveault, Compt. rend. 117 (1893), 177, 1092; 118 (1894), 1154; 119 (1894), 281, 334; 122 (1896), 530, 673.

²⁾ Hesse, Journ. f. prakt. Chem. II. 50 (1894), 472.

³⁾ Ibidem II. 48 (1893), 293; Berl. Berichte 23 (1890), 3191; 27 (1894), Ref. 625.

⁴⁾ Bull. Soc. chim. III. 23 (1900), 458.

⁵⁾ Journ. f. prakt. Chem. II. 50 (1894), 472.

⁶⁾ Nachr. K. Ges. Wiss. Göttingen 1896, Session of February 8.; Chem. Zentralbl. 1896, I. 809.

⁷⁾ Journ. f. prakt. Chem. II. 53 (1896), 42.

⁸⁾ Ibidem II. 49 (1894), 185; comp. also Report of Schimmel & Co. October 1894, 29; April 1896, 44.

⁹⁾ Berl. Berichte 29 (1896), 903; 30 (1897), 33.

¹⁰⁾ Loc. cit. and Compt. rend. 138 (1904), 1699; comp. also Barbier and Bouveault, Compt. rend. 122 (1896), 737.

¹¹⁾ Report of Schimmel & Co. October 1904, 119.

Recent publications by Harries and Himmelmann¹⁾ would seem to indicate that citronellol also consists of a mixture of two isomers, to which two separate formulas should be assigned. This conception may lead to an explanation of the differences in the investigations of citronellol found by Bouveault on the one hand and by Tiemann and Schmidt and Schimmel & Co. on the other hand.

Geraniol and citronellol occur frequently together. In as much as they cannot be separated by fractional distillation either as such or in the form of their esters, and since the calcium chloride method does not admit of a quantitative separation, it was difficult to obtain pure citronellol. In this Wallach²⁾ first succeeded, who observed that when geraniol is heated with water in an autoclave to 250° it is completely decomposed with the formation of hydrocarbons, whereas citronellol remains unchanged. A method of separation suggested by Tiemann and Schmidt³⁾ depends on the action of phosphorus trichloride on the alcohols in ethereal solution. Geraniol is thereby converted partly into hydrocarbons, partly into geranyl chloride; citronellol, however, into a chlorinated acid ester of phosphorous acid which is soluble in alkalis and can thus be separated from the other compounds. The crude citronellol regenerated by the saponification of the ester is purified by distillation with water vapor. A separation of the two can also be effected by heating the mixture of alcohols with phthalic acid anhydride to 200°. Whereas the geraniol is thus destroyed, the citronellol is converted into the acid phthalic acid ester, the sodium salt of which is soluble in water and which can be saponified by means of alcoholic potassa. According to Walbaum and Stephan⁴⁾ the mixture can be heated with strong formic acid, whereby the geraniol is decomposed and the citronellol converted into the formate. According to Barbier and Bouveault⁵⁾ the geraniol can also be destroyed by heating with benzoyl chloride to from 140 to 160°.

¹⁾ Berl. Berichte 41 (1908), 2187.

²⁾ Nachr. K. Ges. Wiss. Göttingen 1896, Session of February, 8.

³⁾ Berl. Berichte 29 (1896), 921.

⁴⁾ Berl. Berichte 33 (1900), 2307.

⁵⁾ Compt. rend. 122 (1896), 530.

Artificially citronellol can be obtained from citronellal, its corresponding aldehyde, by means of reduction with sodium amalgam and glacial acetic acid.¹⁾ Other methods of formation, starting with geranic acid, have been suggested by Tiemann²⁾ and by Bouveault and Gourmand.³⁾ The products thus obtained are optically inactive. Furthermore, by the cleavage of menthonoxime and change in the resulting aliphatic compound, Wallach⁴⁾ obtained an alcohol $C_{10}H_{20}O$ which very much resembles citronellol, but is not identical with it.

Pure citronellol is a colorless oil with an agreeable, rose-like odor, but finer than that of geraniol. According to its method of formation it reveals slight variations in its physical properties. Wallach²⁾ determined the following constants in connection with a citronellol (renniol) obtained according to his method (see above):

b. p. 114 to 115° (12 to 13 mm.); $d_{20} 0.856$; $n_D^{20} 1.45609$;

According to Tiemann and Schmidt,⁴⁾ *d*-citronellol obtained by reduction of citronellal, possesses the following properties:

b. p. 117 to 118° (17 mm.); $d_{17.5} 0.8565$; $[\alpha]_{D^{17.5}} +4$; $n_D 1.45659$.

l-Citronellol, prepared from rose oil by means of the phosphorus trichloride method, boils at 113 to 114° at 15 mm. pressure; $d_{20} 0.8612$; $n_D 1.45789$; and deviates polarized light $4^{\circ}20'$ to the left.⁵⁾

For the alcohol, obtained from Réunion geranium oil according to a method similar to that of Wallach, the following constants are recorded:

b. p. 225 to 226° (764.5 mm.); $d_{15} 0.862$; $n_D 1.45611$).

¹⁾ Dodge, *Americ. chem. Journ.* **11** (1889), 463; Tiemann and Schmidt, *Berl. Berichte* **29** (1896), 906; Erdmann, *Journ. f. prakt. Chem.* **11**, 56 (1897), 38.

²⁾ *Berl. Berichte* **31** (1898), 2899.

³⁾ *Compt. rend.* **138** (1904), 1699.

⁴⁾ *Liebig's Annalen* **278** (1894), 316; **296** (1897), 129.

⁵⁾ *Nachr. K. Ges. Wiss. Göttingen* **1896**, Session of February 8.; Naschold, *Beiträge zur Kenntnis aliphatischer Terpenverbindungen. Inaug.-Dissert.* Göttingen 1896, p. 56.

⁶⁾ *Berl. Berichte* **29** (1896), 906.

⁷⁾ Tiemann and Schmidt, *Berl. Berichte* **29** (1896), 923.

⁸⁾ Report of Schimmel & Co. April 1898, 58.

In the laboratory of Schimmel & Co. the following constants were observed in connection with their own preparations:

Citronellol from Java citronella oil: B. p. 109° (7 mm.); 103° (5 mm.); $d_{15} 0,8604$ to $0,8629$; $\alpha_D + 2^{\circ}7'$ to $+ 2^{\circ}32'$; $n_{D20} 1,45651$ to $1,45791$; m. p. of the silver salt of the acid phthalic acid ester 125 to 126° .¹⁾

Citronellol from geranium oil: B. p. 225 to 226° (764,5 mm.); $d_{15} 0,862$ to $0,869$; α_D slightly laevogyrate to $- 1^{\circ}52'$; $n_{D20} 1,459$ to $1,463$; soluble in about 14 vols. 50 p. c. alcohol and in 3 to 4 vols. of 60 p. c. alcohol.

Citronellol is much more stable than geraniol and is not acted upon when heated with alkali. When shaken with a 10 p. c. sulphuric acid it adds water and is converted into a diatomic alcohol from which dehydrating agents regenerate citronellol.²⁾ Attempts to prepare a cyclic hydrocarbon $C_{10}H_{18}$ by dehydration have not been successful thus far. Its stability toward phosphorus trichloride in the cold, phthalic acid anhydride and formic acid at higher temperatures, and toward the united action of heat and pressure in the presence of water, has already been referred to in the discussion of the methods by which citronellol can be separated from the other alcohols. It is also worth mentioning that sulphurous acid and sodium acid sulphite can be added to the doubly linked carbon atoms of citronellol.

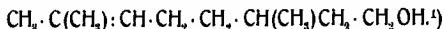
As a primary alcohol, citronellol first yields the aldehyde citronellal, $C_{10}H_{18}O$, which, upon reduction with sodium amalgam, can be reconverted into the alcohol. As is the case with geraniol, the oxidation to the aldehyde is by no means quantitative, other oxidation products, such as citronellic acid, &c., resulting.³⁾ If citronellol is first hydroxylized with dilute permanganate solution and the resulting glycol oxidized further with chromic acid mixture, acetone and β -methyladipinic acid result. According to the optical character of the citronellol, the latter oxidation product is obtained more or less active, or optically inactive. The melting point also varies accordingly from 82 to 96° . In as much as

¹⁾ Report of Schimmel & Co. April 1902, 14.

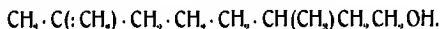
²⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 907.

³⁾ Tiemann and Schmidt, Berl. Berichte 30 (1897), 34.

citronellol can also be converted into the cyclic alcohol *isopulegol* and this into *pulegone*, it has been assigned the formula dimethyl-2,6-octene-2-ol-8.



Opposed to this view are the observations of Harries and Himmelmann,²⁾ referred to above, also those of Bouveault, *viz.*, that citronellol is a mixture of two isomeric alcohols; to one of which may be assigned the above formula and to the other the formula



The esters of citronellol, of which the acetate occurs in volatile oils, are readily obtained by the action of the corresponding acid anhydrides on the alcohol. For further statements see under esters.

The acid phthalic acid ester, which results when citronellol and phthalic acid anhydride are heated together, differs from that of geraniol in being liquid. However, it yields a well crystallizable silver salt from which pure citronellol can be regenerated.³⁾

Citronellol can be characterized by its oxidation to citronellal (which see) and this in turn by means of its citronellyl- β -naphthocinchonic acid, or by means of its semicarbazone⁴⁾ which melts at 84°. In the absence of geraniol, citronellol can be identified by means of the silver salt of citronellyl phthalic acid which melts at 125 to 126°. Its identification by means of the citronellyl-pyruvic acid ester, the semicarbazone of which melts at 110 to 111°, can be carried out in the presence of geraniol. For the quantitative determination of citronellol in the presence of other alcohols, its stability toward concentrated formic acid is resorted to. Whereas the other alcohols are destroyed, citronellol, under certain conditions, is converted into the formate. For further details see the chapter "The examination of volatile oils".

¹⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 908.

²⁾ Berl. Berichte 41 (1908), 2187.

³⁾ Erdmann and Huth, Journ. f. prakt. Chem. II. 56 (1897), 41.

⁴⁾ Tiemann and Schmidt, Berl. Berichte 30 (1897), 34; 31 (1898), 3307. However, other semicarbazones with different melting points are known. See under citronellal.

Of other alcohols, found in volatile oils, that are regarded as aliphatic compounds, the following should be mentioned:

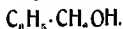
*Androl*¹⁾ is the name assigned to an alcohol of like composition with citronellol, which appears to impart to water fennel (*Phellandrium aquaticum*) its characteristic odor. It may be recognized by its physical constants (b. p. 197 to 198°; $d_{15} = 0.858$; $n_D^{20} = 1.44991$) and by its phenylurethane which melts at 42 to 43°. Nothing further is known about its constitution.

Uncineol, $C_{10}H_{18}O$, is the name given by Baker and Smith²⁾ to an alcohol which they found in that portion of cajuput oil (*Malaleuca uncinata*) which boils above 197°. When pure, this alcohol consists of snowwhite crystalline needles which melt at 72.5°; $[\alpha]_D^{20} + 36.99^\circ$ in alcoholic solution.

An alcohol with a rose-like odor has also been found in fraction 230° of waterfennel oil.³⁾ Its phenylurethane melts between 87 to 90°. In patchouli oil⁴⁾ there likewise has been found an alcohol with a rose-like odor. However, nothing further has as yet been recorded.

CYCLIC (AROMATIC) ALCOHOLS.

Benzyl alcohol.



This alcohol, which is of importance because of its application in perfumery, has been found as such in the oils of tuberose, ylang-ylang, jasmin, cloves and of cassia flowers (*Acacia Farnesiana* and *A. Cavenia*). Possibly it is also found in small amounts in cherry laurel oil. As acetate it occurs in the oils of ylang-ylang, hyacinth, jasmin and gardenia; as benzoate in the oils of tuberose, ylang-ylang, Peru balsam and tolu balsam; as cinnamate in storax oil and in the two balsams just mentioned; as salicylate in ylang-ylang oil; and as phenyl acetic acid ester in neroli oil.

¹⁾ Report of Schimmel & Co. October 1904, 92.

²⁾ Journ. and Proceed. Royal Soc. of N. S. W. 41 (1907), 196.

³⁾ Report of Schimmel & Co. October 1904, 92.

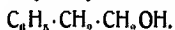
⁴⁾ Report of Schimmel & Co. April 1904, 69.

It is prepared by heating benzyl chloride with water and freshly precipitated lead oxide to 100° or by prolonged heating of the chloride with water or potassium carbonate solution. Or it can be obtained, as suggested by Cannizzaro,¹⁾ by double decomposition between benzyl chloride and potassium acetate and subsequent saponification of the benzyl acetate. Still another method consists in shaking benzaldehyde with alkali, whereby one half of the aldehyde is oxidized, the other half reduced. In order to remove the last traces of aldehyde the alcohol is shaken with an acid sulphite solution before it is distilled. In this case the sulphurous acid should be washed out with alkali. Otherwise the sulphuric acid resulting will convert a large part of the benzyl alcohol into the benzyl ether.²⁾

Benzyl alcohol is a colorless liquid which, when freshly prepared, has a faintly aromatic odor. Upon exposure to air it oxidizes and assumes an odor of bitter almond oil. B. p. 205°; d_{16}^4 1.05; $n_{D_{20}}^{20}$ about 1.540. It is soluble in about 35 vols. of water, in 8 to 9 vols. of 30 p. c. alcohol and in 1.5 vol. of 50 p. c. alcohol. With other solvents it is miscible in all proportions. In as much as it can be prepared from benzyl chloride, special care should be devoted in its examination to the test for chlorides. (For details see the chapter "The examination of volatile oils".)

Upon oxidation benzaldehyde and benzoic acid result. Characteristic derivatives are the phenylurethane³⁾ melting at 78° and acid phthalic acid ester melting at 106 to 107°.⁴⁾ The semicarbazone of the pyruvic acid ester (m. p. 176°)⁵⁾ may also be used for this purpose.

Phenylethyl alcohol.



Phenylethyl alcohol, which is used in the preparation of artificial volatile oils, has been observed as constituent of the

¹⁾ Liebig's Annalen 96 (1855), 246.

²⁾ Meisenheimer, Berl. Berichte 41 (1908), 1420.

³⁾ Report of Schimmel & Co. April 1899, 28, footnote.

⁴⁾ *Ibidem* October 1900, 19.

⁵⁾ Masson, Compt. rend. 149 (1909), 630.

leaf oil of *Pinus halepensis*, of oil of rose (especially that distilled from dried rose leaves) and of neroli oil. In the oils of rose and neroli, the alcohol appears also to be combined as ester with benzoic acid and phenylacetic acid.

Artificially it can be prepared from phenyl acetaldehyde by reduction with sodium amalgam;¹⁾ likewise from phenylacetic acid esters by reduction with sodium and absolute alcohol, a method patented by Bouveault and Blanc.²⁾ In connection with a preparation, made in the laboratory of Schimmel & Co. according to the latter method and purified by means of the calcium chloride compound, the following constants were observed:

B. p. 220 to 222° (740 mm.), abt. 104° (12 mm.), 93° (6 mm.); d_{15}° 1,0242; n_{D20}° 1,53212.

According to observations thus far made the latter two constants for technical products fall within the following limits:

d_{15}° 1,023 to 1,024; n_{D20}° 1,532 to 1,533.

Phenylethyl alcohol is a colorless liquid that is optically inactive and possesses a very mild and faint odor. As a result of its partial oxidation to phenyl acetaldehyde it becomes honey-like in consistency in the course of time. It is readily soluble in all of the common organic solvents. It is soluble in 2 vols. of 50 p. c. alcohol and in 18 vols. of 30 p. c. alcohol. Even in water it is soluble in the ratio of 1:60. Because of this appreciable solubility in water, rose oil contains only a small fraction of the phenylethyl alcohol found in the leaves. The larger part of the alcohol remains in the aqueous distillate from which it cannot be separated by cohobation because of its great dilution.

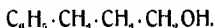
With anhydrous calcium chloride phenylethyl alcohol forms a solid compound which can be used for its purification. Oxidation with chromic acid mixture yields phenyl acetaldehyde and phenylacetic acid, at times also its phenylacetic acid ester which

¹⁾ Radziszewski, Berl. Berichte 9 (1876), 372.

²⁾ G. I. P. 164294. Comp. also Compt. rend. 186 (1903), 1676 and 187 (1903), 60.

melts at 28°. For the identification of phenylethyl alcohol its phenylurethane (m. p. 80°), its diphenylurethane (m. p. 99 to 100°) and acid phthalic acid ester (m. p. 188 to 189°) are used.

Phenylpropyl alcohol.



As cinnamic acid ester, normal phenylpropyl alcohol has been found in several resins and balsams, e. g. in Sumatra benzoës, in Oriental and American styrax and in the Honduras balsam which is frequently misnamed white Peru balsam. Probable is likewise its occurrence as cinnamate in xanthorrhœa resin and as acetate in cassia oil.

The phenylpropyl alcohol isolated from the above named resins is always accompanied by cinnamic alcohol from which it cannot be separated completely by fractionation. According to the method patented by Schimmel & Co.¹⁾ it can be obtained in a pure state by heating the mixture of alcohols with an equal part of concentrated formic acid. The cinnamic alcohol is thus resinified whereas the phenylpropyl alcohol is converted into the formate. The ester can be distilled with steam and then saponified.

Synthetically phenylpropyl alcohol can be obtained by the reduction of cinnamic alcohol with sodium amalgam in the presence of much water;²⁾ or, according to the method of Bouvcault and Blanc,³⁾ by the reduction of cinnamic acid ester or the benzylacetic acid ester with sodium and absolute alcohol.

Phenylpropyl alcohol is a colorless, thick liquid possessing a faint peculiar odor resembling somewhat that of cinnamic alcohol and reminding of certain species of hyacinth. In ordinary solvents it is readily soluble. It is soluble in all proportions in 70 p. c. alcohol, in 1.5 vols of 60 p. c. alcohol and in about 3 vols. of 50 p. c. alcohol. In water it is not soluble in the ratio of 1:300.

¹⁾ G. I. P. 116091. Comp. Chem. Zentralbl. 1901, I. 69.

²⁾ Rügheimer, Liebig's Annalen 172 (1874), 123. Comp. also Hatton and Hodgkinson, Chem. News 43 (1881), 1930; Chem. Zentralbl. 1881, 407.

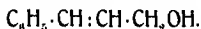
³⁾ G. I. P. No. 164294.

In the above mentioned patent, Schimmel & Co. record the following constants:

B. p. 235° , resp. 119° (12 mm.); $d_{15} 1.007$.

When oxidized with chromic acid in glacial acetic acid, it yields hydrocinnamic acid (m. p. 49°). It can be more readily identified by its phenylurethane¹⁾ melting at 47 to 48° .

Cinnamic alcohol.



Cinnamic alcohol, formerly also designated styrene, is found in volatile oils, not as such, but as ester. As acetate it occurs in cassia oil; as cinnamate (styracin) in storax, also in the oils of hyacinth (?), xanthorrhoea resin, Peru balsam and Honduras balsam.

It is commonly obtained by saponification of the styracin in storax. Synthetically it can be obtained by reduction of cinnamic aldehyde diacetate and subsequent saponification of the resulting cinnamyl acetate.²⁾

Cinnamic alcohol occurs in long, fine white needles which possess a hyacinth-like odor. At 33° they melt to a colorless, strongly refractive liquid, which boils at 257.5° (758 mm.), respectively at 117° (5 mm.) At 36° its specific gravity lies between 1.01 and 1.03. In water it is sparingly soluble (about 1:250), also in petroleum ether. In the other solvents it is readily soluble. Of 30 p. c. alcohol about 50 to 60 vols., of 50 p. c. alcohol 4 to 5 vols. and of 60 p. c. alcohol about 2 vols. are needed to effect solution.

With platinum black, cinnamic alcohol is oxidized to cinnamic aldehyde, upon more violent oxidation to cinnamic acid (m. p. 133°) and finally to benzaldehyde and benzoic acid. Upon reduction with sodium amalgam in the presence of much water it can be converted into phenylpropyl alcohol.

¹⁾ Walbaum, Berl. Berichte 83 (1900), 2300, footnote.

²⁾ Barbier and Léser, Bull. Soc. chim. III. 83 (1905), 858.

Characteristic derivatives are the phenylurethane melting at 90 to 91.5° and the diphenylurethane melting at 97 to 98°.¹⁾ The latter is to be preferred to the phenylurethane since it has the more sharply marked melting point.

ALICYCLIC (HYDROAROMATIC) ALCOHOLS.

Dihydrocuminic alcohol.

This alcohol, the constitution of which has not yet been definitely determined, was recently found in the laboratory of Schimmel & Co.,²⁾ to occur free and as ester, also in both optical modifications in gingergrass oil.

This alcohol is a colorless, rather viscid oil of a peculiar odor reminding of linalool and terpineol. From geraniol, its companion in gingergrass oil, it can be separated only with difficulty. Its isolation can best be effected by heating the mixture of alcohols with 2 parts of 90 p. e. formic acid on a waterbath to a temperature of 80 °,³⁾ whereby only the geraniol is destroyed. For two preparations thus purified, Walbaum and Hühlig⁴⁾ record the following constants:

B. p. 226 to 227° (767 mm.), 92 to 93.5° (5 mm.); $d_{15} = 0.9510$; $n_D = 1.3818$; $n_{D20} = 1.49629$.

B. p. 228 to 229° (755 mm.), 94 to 96° (4 to 5 mm.); $d_{15} = 0.9536$; $n_D = 1.3851$; $n_{D20} = 1.49761$.

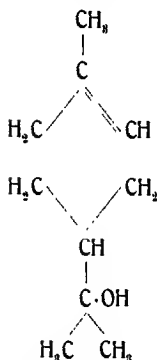
When oxidized with Beckmann's chromic acid mixture, dihydrocuminic aldehyde, $C_{10}H_{14}O$, results, thus proving that the alcohol in question, $C_{10}H_{16}O$, is a dihydrocuminic alcohol. Since no crystalline derivative of the alcohol has yet been obtained, it is identified by its oxidation to the aldehyde, the semicarbazone of which melts at 198 to 198.5°.

¹⁾ Report of Schimmel & Co. April 1910, 173.

²⁾ Report of Schimmel & Co. April 1904, 57; October 1904, 44; Walbaum and Hühlig, Jour. f. prakt. Chem. II. 71 (1905), 464.

³⁾ Stronger formic acid and higher temperatures are to be avoided since the alcohol is thereby dehydrated to cymene. Even when the precautions stated are taken this change will take place to a slight extent.

⁴⁾ Loc. cit. 466.

α-Terpineol.

By the action of dilute sulphuric acid on terpin hydrate (see p. 384) the liquid terpincol of commerce results. This, however, is not a chemical unit, but a mixture of isomeric compounds $\text{C}_{10}\text{H}_{18}\text{O}$, among which the α -terpineol, m. p. 35° , predominates. The presence of β -terpineol, m. p. 32° ¹⁾ and the liquid terpineol-1²⁾ has likewise been established.

In nature there apparently occurs only the α -terpineol, either optically active or inactive, the constitution of which has been established by the researches of Wallach,³⁾ Wagner,⁴⁾ Semmler and Tiemann.⁵⁾ Although liquid terpinols have been isolated, it seems highly probable that they can be obtained in the solid condition.

Solid d - α -terpineol has been observed in the oils of Malabar cardamom, sweet oranges, petit-grain, neroli, in Cayenne- and the lavogyrate Mexican lignaloc oils, also in oil from lovage-root. In Malabar cardamom oil it occurs probably for the most part as acetate. As ester only, namely as acetate and valerianate (?),

¹⁾ Stephan and Helle, Berl. Berichte 35 (1902), 2147.

²⁾ Wallach, Liebig's Annalen 356 (1907), 218; 362 (1908), 269.

³⁾ Liebig's Annalen 276 (1893), 103, 150; 277 (1893), 110; 291 (1896), 342; Berl. Berichte 28 (1895), 1773.

⁴⁾ Berl. Berichte 27 (1894), 1652, 2273.

⁵⁾ Semmler, Berl. Berichte 28 (1895), 2189; Tiemann and Semmler, *ibidem* 28 (1895), 1778; Tiemann and Schmidt, *ibidem* 1781; Tiemann, *ibidem* 29 (1896), 2616.

it occurs in cypress oil. In liquid form it has been isolated from marjoran oil.

Solid *l*- α -terpinol has been found in the wood turpentine oil from *Pinus palustris*, in camphor oil, in the oil from the leaves of *Laurus Camphora*, in the dextrogyrate Mexican lignaloc oil, in limette oil and niaouli oil, in the last mentioned also as valcrianate. As a liquid it has been isolated from Canada snakeroot oil, the bark oil from *Ocotea usambarensis* and both free and as ester in European wormseed oil.

Solid *i*-terpineol has been isolated from cajeput oil in which it also occurs as acetate. As a liquid it has been obtained from the oils of nutmeg and boldo leaves.

Without reference as to angle of rotation, the presence of terpineol has been recorded for the following oils: kuromoji oil, lemon oil, oil of *Melaleuca uncinata* (?), gardenia oil, valcrian oil (?), kassia root oil and crigeron oil. Probably the acetate also occurs in the German oil of *Pinus sylvestris*.

According to the statement of Bouchardat and Voiry,¹⁾ solid inactive terpinol m. p. 30 to 32° is formed by the action of very dilute sulphuric acid on terpin. However, it has not yet been definitely settled whether this is α - or β -terpineol. The solid, optically active modifications of α -terpineol can be obtained either, according to the method of Semmler,²⁾ by boiling the *d*- or *l*-limonene monobromhydrate with the oxides of silver or lead; or, according to Wallach³⁾ by shaking limonene monochlorhydrate with dilute potassium hydroxide solution, or by shaking homonopinol with dilute sulphuric acid.⁴⁾ The simplest method is to prepare them as acetates by the simultaneous action of glacial acetic acid (comp. under camphene, p. 305) and sulphuric acid on limonene, or by the action of glacial acetic acid and zinc chloride on pinene.⁵⁾ Noteworthy is also the formation of optically active solid terpineols from linalool by the action of acetic acid

¹⁾ Compt. rend. 104 (1887), 996.

²⁾ Berl. Berichte 28 (1895), 2189.

³⁾ Liebig's Annalen 350 (1906), 154.

⁴⁾ Liebig's Annalen 360 (1908), 98.

⁵⁾ Ertchikowsky, Journ. russ. phys. chem. Ges. 28 (1896), 132. According to Bull. Soc. chim. III, 16 (1896), 1584.

anhydride or formic acid,¹⁾ also of solid inactive terpineol from geraniol and formic acid.²⁾

The solid inactive α -terpineol possesses the elder-blossom-like odor of the liquid to a slight degree only. It is very readily soluble in organic solvents and possesses the following properties:

M. p. 35° ³⁾; b. p. 217 to 218° (760 mm.), 104 to 105° (10 mm.); $d_{15^{\circ}}$ 0,935 to 0,940; $n_{D20^{\circ}}$ 1,48084.⁴⁾

The following constants were observed in the laboratory of Schimmel & Co.:

M. p. 35° ; b. p. 85° (3 mm.); $d_{15^{\circ}}$ (supercooled) 0,9386; $n_{D20^{\circ}}$ 1,48268.

In connection with a strongly active α -terpineol, obtained by shaking homonopinol with dilute sulphuric acid, Wallach⁵⁾ observed the following constants:

M. p. 37 to 38° ; b. p. 218 to 219° ; $[\alpha]_D - 106^{\circ}$ in 16,34 p. c. ethereal solution.

The optical activity is variable. The highest deviation observed in connection with a natural terpineol is $[\alpha]_D + 95^{\circ} 9'$ for the *d*-terpineol from oil of orange,⁶⁾ and $[\alpha]_D - 27^{\circ} 20'$ for the *l*-terpineol from lignacoe oil.⁷⁾ The highest deviation has been revealed by an artificially prepared *l*-terpineol, namely $[\alpha]_D - 117,5^{\circ}$.⁸⁾

In connection with the commercial liquid products of their own manufacture, which consist only in part of α -terpineol and contain some β -terpineol and terpinenol-1, Schimmel & Co. observed the following constants:

B. p. 217 to 219° ; $d_{15^{\circ}}$ 0,935 to 0,940; $\alpha_D + 0^{\circ}$; $n_{D20^{\circ}}$ 1,481 to 1,484; soluble in about 9 vols. 50 p. c. alcohol, in 3 to 5 vols. of

¹⁾ Stephan, Journ. f. prakt. Chem. II. 58 (1898), 109.

²⁾ Stephan, *ibidem* 60 (1899), 244.

³⁾ Wallach, Liebig's Annalen 275 (1893), 104.

⁴⁾ Stephan, Journ. f. prakt. Chem. II. 58 (1898), 110; 60 (1899), 244.

⁵⁾ Liebig's Annalen 360 (1908), 89.

⁶⁾ Stephan, Journ. f. prakt. Chem. II. 62 (1900), 530.

⁷⁾ Report of Schimmel & Co. October 1905, 48.

⁸⁾ Ertchikowsky, Journ. russ. phys. chem. Ges. 28 (1896), 132. According to Bull. Soc. chim. III. 16 (1896), 1584.

60 p. c. alcohol, and in abt. 2 vols. of 70 p. c. alcohol. With petroleum ether it should be miscible in all proportions, *i. e.* it should be free from water.

As to their chemical properties the inactive and both active modifications of α -terpineol behave alike. The derivatives, however, differ in part:

| | Inactive modifications | Active modifications |
|----------------------------|------------------------|----------------------|
| Melting point | 35° | 37 to 38° |
| Nitrosochloride | 112 to 113° | 107 „ 108° |
| Nitrolpiperidide | 159 „ 160° | 151 „ 152° |
| Methoethyl heptanonolid | 64° | 46 „ 47° |

α -Terpineol is a tertiary, unsaturated alcohol which yields addition products with bromine, nitrous acid anhydride, nitrogen-tetroxyde and nitrosylchloride. The nitrosochloride and the nitrolamine bases derived therefrom are especially adapted for the characterization of the α -terpineol (see p. 380).

The liquid dibromide yields a tribromide when treated with hydrogen bromide in glacial acetic acid solution. Further treatment with bromine converts it into dipentene tetrabromide melting at 124°.

With hydrohalogen acids the corresponding dipentene dihalogen hydrides result. The dihydriodide $C_{10}H_{16}I_2$ (m. p. 77 to 78°), obtained by shaking the alcohol with concentrated hydriodic acid, can be utilized for the identification of terpineol.¹⁾ Toward mineral acids and also toward some organic acids, terpineol is rather unstable. Whereas shaking with dilute sulphuric acid hydrates it to terpinhydrate,²⁾ boiling therewith causes it to be dehydrated with the formation of terpinene together with a little dipentene and cineol. Potassium acid sulphate has a similar effect producing principally dipentene; also phosphoric acid producing principally terpinolene with small amounts of terpinene and cineol; also oxalic acid which likewise produces terpinolene.³⁾ Acetic acid anhydride also dehydrates terpineol, especially when heated, producing dipentene. Hence it is not possible to esterify

¹⁾ Wallach, Liebig's Annalen 230 (1885), 265.

²⁾ Tiemann and Schmidt, Berl. Berichte 28 (1895), 1781.

³⁾ Wallach, Liebig's Annalen 275 (1893), 104; Baeyer, Berl. Berichte 27 (1894), 447.

terpineol quantitatively with this agent without exercising special precautions.¹⁾ For further details concerning terpinylacetate see the chapter on esters.

When oxidized with dilute permanganate solution, terpineol is first converted into the polyatomic alcohol $C_{10}H_{20}O_3$, 1,2,8-trihydroxymenthane (m. p. of the inactive modification 122°). Chromic acid mixture oxidizes this to a ketolactone $C_{10}H_{18}O_3$ (m. p. of the active modification 46 to 47°, of the inactive 64°). The study of this compound has contributed much toward the establishment of the constitution of terpineol as expressed by the formula Δ^1 -terpene-8-ol. More violent oxidation of the terpineol and of the ketolactone with chromic acid mixture or nitric acid yields terphenyl and terebinic acids.²⁾

Of special interest is the conversion of terpinol, through the tribromide and the nitrosochloride, into derivatives of carvone.³⁾

The hydroxy group of terpinol reacts with phenylisocyanate when both compounds are mixed and set aside at room temperature for a time. Sometimes crystals of diphenylurca separate at first, from which the liquid mixture is separated with the aid of cold anhydrous ether or, better still, with low boiling petroleum ether. After careful evaporation of the solvent, the urethane separates in fine needles. Recrystallized from alcohol, the inactive compound melts at 113°.⁴⁾ The urethane obtained from optically active terpineol is likewise inactive. The α -naphthylurethane,⁵⁾ melting at 147 to 148° can also be utilized for the identification of α -terpineol. Especially suited to this purpose is the nitrosochloride.

According to Wallach⁶⁾ the preparation of the nitrosochloride is accomplished in the following manner: To a solution of 15 g. terpineol in 15 ccm. glacial acetic acid and 11 ccm. ethylnitrite,

¹⁾ Ginsberg, Journ. russ. phys. chem. Ges. 29 (1897), 249. According to Chem. Zentralbl. 1897, II. 417; Report of Schimmel & Co. October 1897, 63. Compare also the chapter "Examination of volatile oils" under acetylation.

²⁾ Wallach, Liebig's Annalen 227 (1893), 117, 120; 291 (1896), 345; Berl. Berichte 29 (1895), 1775; Tiemann and Mahla, Berl. Berichte 29 (1896), 928; Tiemann, *ibidem* 2616.

³⁾ Wallach, Liebig's Annalen 281 (1894), 140; 291 (1896), 346.

⁴⁾ Wallach, Liebig's Annalen 275 (1893), 104.

⁵⁾ Report of Schimmel & Co. October 1906, 41.

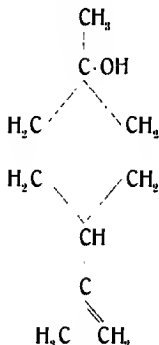
⁶⁾ Liebig's Annalen 277 (1893), 120; 360 (1908), 90.

well cooled in a freezing mixture and while well shaken, 6 ccm. of hydrochloric acid dissolved in an equal volume of glacial acetic acid, are added drop by drop. At the close of the reaction the nitrosochloride is precipitated with ice water in the form of an oil which, however, soon crystallizes. The solid compound is purified by recrystallization from hot acetic ether or methyl alcohol and melts at 112 to 113°. The active modification melts at 107 to 108°.

With piperidine in alcoholic solution, the nitrosochloride yields the nitropiperidine base $C_{10}H_{17}(OH)NONC_5H_{10}$, which is difficultly soluble in ether, crystallizes from methyl alcohol in needles that melt at 159 to 160°. These data by Wallach refer to the derivative obtained from an optically inactive terpineol. The nitrol piperidine obtained from an optically active material melts several degrees lower, namely at 151 to 152°.¹⁾

With aniline a terpineol nitrolanilide, m. p. 155 to 156°, is obtained.

β -Terpineol.



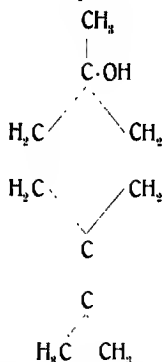
As already mentioned under α -terpineol, β -terpineol results together with α -terpineol when terpin hydrate is acted upon by dilute acids. Thus far β -terpineol has not been found in volatile

¹⁾ Report of Schimmel & Co. October 1897, 11; Wallach, Liebig's Annalen 360 (1908), 90.

oils. Schimmel & Co.¹⁾ have isolated the inactive modification from fraction 212 to 215° of commercial terpineol by freezing. It crystallizes in needles that melt at 32 to 33°; b. p. 209 to 210° (752 mm.); $d_{16} 0.923$ (in the supercooled condition); $n_{D20} 1.47470$.

Of its derivatives the following may here be mentioned: the nitrosochloride (m. p. 103°),²⁾ the nitrolpiperidine base (m. p. 108°), the nitrolaniline base (m. p. 110°) and the phenylurethane (m. p. 85°). When oxidized with permanganate, γ -terpineol yields trihydroxy-terpane melting at 118°.

γ -Terpineol.



γ -Terpinol has not yet been found in nature. v. Baeyer³⁾ obtained it by reducing tribrom-1,4,8-terpane, which in time he had obtained by brominating dipentene dihydrobromide.

It also results when terpin is heated with oxalic acid or phosphoric acid.⁴⁾

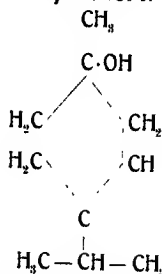
Recrystallized from ether, γ -terpineol forms thick prisms melting at 69 to 70°, which possess the agreeable odor of elder-blossoms. In order to identify γ -terpineol, it can be converted into the acetate, the blue nitrosochloride of which melts at 82°.

¹⁾ Report of Schimmel & Co. April 1901, 79; Stephan and Helle, Berl. Berichte 35 (1902), 2147.

²⁾ Wallach, Liebig's Annalen 345 (1903), 128; Comp. also Wallach, *Terpene u. Campher*, p. 333.

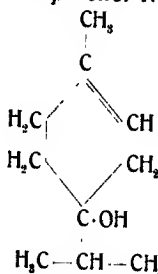
³⁾ Berl. Berichte 27 (1894), 443.

⁴⁾ *Ibidem* 715.

Terpinenol-1.

This alcohol also has not yet been found in volatile oils. Of interest is its occurrence in the first fraction of commercial liquid terpineol.¹⁾ Synthetically it was prepared by Wallach²⁾ from *Δ*³-isopropylhexenone. — B. p. 208 to 210°; d_{40}^{20} 0.9265; $n_{D, 20}^{20}$ 1.4781.¹⁾

With hydrohalogens the alcohol is converted into terpinene derivatives. Oxidation with dilute permanganate solution converts it into 1,3,4-trihydroxyterpane, m. p. 120 to 121°. Further oxidation converts it into α, α' -dihydroxymethyl isopropyladipinic acid, m. p. 189°. When heated with acids the trihydroxyterpane yields a mixture of *p*-cymene and *A*¹-menthenone, the semicarbazone of which melts at 224 to 225°. These compounds can be utilized for the identification of terpinenol-1.

Terpinenol-4.

This alcohol which in its general characteristics closely resembles α -terpineol, is derived from terpinene. It has been dis-

¹⁾ Wallach, Liebig's Annalen 356 (1907), 218.

²⁾ *Ibidem* 362 (1908), 280.

covered only recently. In nature it has been found in the oils of juniper, Ceylon cardamoms, nutmeg, marjoram and European wormseed. Synthetically, the active modification has been obtained by shaking sabinene, sabinene hydrate and thujene with dilute sulphuric acid,⁴⁾ the inactive modification by shaking terpinene dihydrochloride with dilute potassium hydroxide solution. (Comp. also p. 320.)

The properties of the active modification have been recorded as follows:

B. p. 209 to 212°; d_{15}^{20} 0.9265; $n_D^{20} + 25^{\circ} 4'$; $n_{D,15}^{20}$ 1.4785.⁵⁾

Those of the inactive modification are:

B. p. 212 to 214°; d_{15}^{20} 0.9290; n_D^{20} 1.4803.⁶⁾

This alcohol is known only in the liquid condition. Its odor is less pleasant than that of terpineol. When acted upon in glacial acetic acid solution with hydrohalogen the corresponding terpinene dihydrohalides result. When shaken with dilute sulphuric acid terpinene terpin, m. p. 137°, results. In as much as this hydration is much slower than that of terpineol to terpin hydrate, this serves as a means for the separation of the two alcohols.

Upon oxidation with dilute permanganate solution, Δ^1 -terpinenol-4 yields in the main 1,2,4-trihydroxyterpane, $C_{10}H_{17}(OH)_3$. With its water of crystallization it melts at 116 to 117°, freed therefrom at 128 to 129°; $[\alpha]_D^{20}$ abt. 21.5°. When distilled with hydrochloric acid, this compound yields carvenone (m. p. of the semicarbazone 200 to 201°), with little cymene. Upon further oxidation with alkaline permanganate solution a mixture of active and inactive α, α' -dihydroxy- α -methyl- α' -isopropyl-adipinic acid, $C_{10}H_{18}O_6$, results. It melts at 205 to 206°, respectively at 188 to 189°. Distilled with steam they readily pass over in the form of the volatile dilactones which melt at 63 to 64° and 72 to 73° respectively. By more energetic oxidation the dihydroxy acid yields ω -dimethyl acetonyl acetone as "Ab-

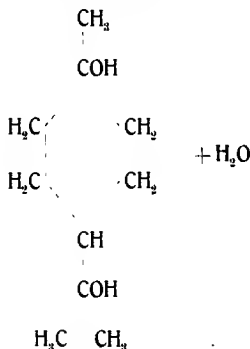
⁴⁾ Wallach, Liebig's Annalen 356 (1907), 215; 360 (1908), 94, 97; 362 (1908), 279; Ber. Berichte 40 (1907), 594.

⁵⁾ Wallach, Liebig's Annalen 356 (1907), 215.

⁶⁾ *Ibidem* 350 (1906), 155.

bau" product. The melting point of its dioxime is 137° , that of its semicarbazone 201 to 202° .

Terpinhydrate.



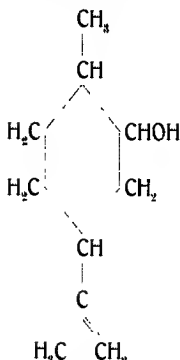
From the theoretical and historical points of view, terpinhydrate is an important compound. But technically also it is of importance as the material from which terpincol is made. (Comp. p. 375.) It is readily formed from turpentine oil by letting this stand with water containing an acid. It is characterized by a remarkable capacity for crystallization, hence it was observed relatively early. According to older statements, terpinhydrate is said to occur in the oils of cardamom and basilicum. However, these statements have not been substantiated by recent observations. This much appears certain that the terpinhydrate was not present in the original oil but must have been formed upon prolonged standing.

Terpinhydrate melts at 116 to 117° . When heated, it loses a molecule of water with the formation of anhydrous terpin which melts at 104 to 105° and boils at 258° (corr.).¹⁾

Terpin exists in two stereoisomeric modifications, namely a *cis*- and a *trans*-form. The *cis*-terpin only, however, is capable of yielding a hydrate.²⁾

¹⁾ Wallach, Liebig's Annalen 290 (1885), 248.

²⁾ Baeyer, Berl. Berichte 26 (1893), 2865.

Dihydrocarveol.

Dihydrocarveol, $\text{C}_{10}\text{H}_{18}\text{O}$, has only recently been found in caraway oil.¹⁾ Artificially prepared it has been known for a longer period. Thus it has been prepared from carvone by reduction with sodium and alcohol; also by the reduction of carvoxime to carvylamine which, upon treatment with nitrous acid, yields dihydrocarveol.

Dihydrocarveol is a liquid which possesses the following properties:

B. p. 224° ; $d_{20} 0.935$; $n_D 1.48506$ (for dihydrocarveol from dihydrocarvylamine).²⁾

B. p. 112° (14 mm.), 224 to 225° (under ord. pressure); $d_{20} 0.927$; $n_D 1.48168$ (for dihydrocarveol from carvone).³⁾

In the laboratory of Schimmel & Co. the following constants were observed in connection with a dihydrocarveol isolated from caraway oil:

B. p. 100 to 102° (7 to 8 mm.); $d_{15} 0.9368$; $\alpha_D -6^\circ 14'$; $n_{120} 1.48364$.⁴⁾

Dihydrocarveol deviates the ray of polarized light in the same direction as does the carvone used for its preparation.

¹⁾ Report of Schimmel & Co. April 1905, 20.

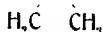
²⁾ Wallach, Berl. Berichte 24 (1891), 3990.

³⁾ Wallach, Liebig's Annalen 275 (1893), 111.

⁴⁾ Report of Schimmel & Co. April 1905, 20.

When oxidized with chromic acid in glacial acetic acid,¹⁾ dihydrocarvone results (b. p. 221 to 222°; $d_{15} 0.928$; $n_D 1.47174$). The dihydrocarvone from *d*-dihydrocarveol is *laevogyrate*, that from *l*-dihydrocarveol is *dextrogyrate*. The corresponding active dihydrocarvoxime melts at 88 to 89°, the inactive modification at 115 to 116°. This oxidation can be utilized for the identification of dihydrocarveol. For this purpose the phenylurethane is also serviceable. The active modifications melt at 87°, the inactive one at 93°.²⁾

Isopulegol.



Isopulegol, $\text{C}_{10}\text{H}_{18}\text{O}$, has not yet been found in volatile oils. It results from citronellal when this is treated with acids. The observation made by Schimmel & Co.³⁾ viz., when the oil of *Barosma pulchellum* is distilled the odor of *isopulegol* is noticeable, is possibly referable to this circumstance.

Isopulegol boils at 91° (13 mm.); $d_{17.5} 0.9154$; $n_D - 2^\circ 40'$; $n_D 1.47292$.⁴⁾

The acetate boils at 104 to 105° (10 mm.).⁵⁾

For purposes of identification, the alcohol is oxidized to *pulegone*⁶⁾ and this characterized by means of its oxime (m. p.

¹⁾ Wallach, Liebig's Annalen 275 (1893), 115.

²⁾ Wallach, *ibidem* 112.

³⁾ Report of Schimmel & Co. April 1909, 96.

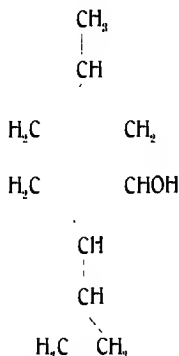
⁴⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 914.

⁵⁾ Barbier and Léser, Compt. rend. 124 (1897), 1309.

⁶⁾ Wallach, Liebig's Annalen 365 (1909), 251.

of the active modification abt. 121° , of the inactive abt. 140° , or its semicarbazone (m. p. of the active modifications 172 to 173° , of the inactive 182 to 183°).

Menthol.



Menthol (peppermint camphor), $\text{C}_{10}\text{H}_{20}\text{O}$, is found in the peppermint oils of which the laevogyrate menthol constitutes the principal constituent. The oil of *Hyptis suaveolens* also consists in large part of menthol, but the direction of its optical rotation has not yet been ascertained. Menthol separates from peppermint oil upon cooling. If the menthol content be large the separation takes place even at ordinary temperature. In peppermint oil, menthol is likewise contained as acetate and isovalerate, also as ester of an acid $\text{C}_8\text{H}_{12}\text{O}_2$. Artificially menthol is obtained from menthone and pulegone.¹⁾ In the presence of an excess of hydrogen, menthone yields menthol only; if, however, solvents are used which themselves do not generate hydrogen with the sodium, menthopinacone is also formed. Both *l*- and *d*-menthone yield according to both methods, also with change of temperature, a strongly laevogyrate mixture from which *l*-menthol (m. p. 43.5°) also a slightly dextrogyrate isomenthol (m. p. 78 to 81° ; $[\alpha]_D + 2^\circ$) can be isolated.²⁾

¹⁾ Beckmann and Pleissner, Liebig's Annalen 202 (1891), 30, 32.

²⁾ Beckmann, Journ. f. prakt. Chem. II. 55 (1897), 19, 30.

Menthol crystallizes in colorless needles or prisms which belong to the hexagonal system. It is characterized by its strong, peppermint-like odor and cooling taste.

Of physical constants the following are recorded:

M. p. 42° ; b. p. $211,5^{\circ}$ (736 mm.).¹⁾

M. p. $42,3$; b. p. $212,5$ (corr. 742 mm.); d_4^{20} 0,890 for solid and d_4^{14} 0,8810 for liquified menthol; $[\alpha]_{D_{40}}^{20} = -49,86'$ likewise for molten menthol.²⁾

b. p. $215,5$ (758 mm.); $\alpha_{D_{31}} = -43\ 45'$ for menthol in super-cooled condition.³⁾

M. p. 43 ; $[\alpha]_{D_{20}} = -49,35$ (in 20 p. c. alcoholic solution), $-50,59$ (in 10 p. c. alcoholic solution):⁴⁾ $n_{D_{13}}^{20}$ 1,4479.⁵⁾

According to recent observations, the melting point of perfectly pure menthol lies between $43,5$ and $44,5$.

Menthol is a saturated secondary alcohol. When dehydrated with potassium acid sulphate, zinc chloride, &c., it is converted mainly into the hydrocarbon $C_{10}H_{18}$, *1st-p*-menthene. The compounds obtained by replacing the hydroxy group by halogen are liquid and little characteristic. With hydrogen iodide and phosphorus it is reduced to hexahydrocymene, $C_{10}H_{20}$.⁶⁾ With chromic acid mixture it is oxidized to the corresponding ketone $C_{10}H_{18}O$, menthone.⁷⁾ With potassium permanganate the same oxidation products result that are obtained from the oxidation of menthone, viz., ketomenthylic acid and β -methyladipic acid melting at 88 to 89° . As a result of these oxidation experiments the above-mentioned formula has been assigned to menthol. This formula has been strengthened by the conversion of menthone into 3-chloreymene effected by Jünger and Klages.⁸⁾ That menthol

¹⁾ Arth, Annal. de Chim. et Phys. VI. 7 (1886), 438.

²⁾ Long, Chem. Zentralbl. 1892, II, 525.

³⁾ Power and Kleber, Pharm. Rundschau (New York) 12 (1894), 162; Arch. der Pharm. 212 (1894), 647, 653.

⁴⁾ Beckmann, Liebig's Annalen 250 (1889), 327; Journ. f. prakt. Chem. II. 33 (1897), 15.

⁵⁾ Brühl, Berl. Berichte 21 (1888), 457, table.

⁶⁾ Berkenheim, Berl. Berichte 25 (1892), 688.

⁷⁾ Beckmann, Liebig's Annalen 250 (1889), 325.

⁸⁾ Berl. Berichte 29 (1896), 314.

could be converted into cymene by heating it with anhydrous copper sulphate to 250 to 280° had previously been demonstrated by Brühl.¹⁾

Of menthol esters a considerable number has been prepared. The above mentioned acetate, also the *isovalerate* are described in the chapter on "Esters". For other esters special reference should be had to the paper by Tschugaeff²⁾ who has given special attention to their optical rotation.

According to Monteil,³⁾ chloral yields two liquid compounds with menthol, *viz.*, chloralmonomenthol and chloraldimenthol. They result upon melting together the calculated amounts of the components.

Owing to the peculiar physical properties of menthol, its identification ought to afford but few difficulties. If necessary its phenylurethane obtained by the action of phenylisocyanate on menthol may be utilized. This derivative, which was first prepared by Leuekart, melts at 111 to 112° and turns the plane of polarized light in the same direction as does menthol. It can be decomposed by sodium ethylate, but the menthol is thereby inactivated.⁴⁾

Other derivatives by means of which menthol can readily be characterized, are menthylbenzoate, resulting upon heating menthol with benzoic acid anhydride, which is difficultly volatile with water vapor and which melts at 54.5°;⁵⁾ the dimenthyl ester of oxalic acid, melting at 67 to 68°; the dimethyl ester of succinic acid, melting at 62°; the monomenthyl ester of phthalic acid, melting at 110° and the dimenthyl ester of the same acid melting at 133°.

A mixture of menthol and menthone can be separated by converting the latter into its oxime and shaking out the oxime from the ethereal solution by means of dilute sulphuric acid.⁶⁾

¹⁾ Berl. Berichte 24 (1891), 3374.

²⁾ Berl. Berichte 31 (1898), 364.

³⁾ Union Pharm. Acc. to Zeitschr. d. allg. österr. Apoth. Ver. 46 (1908), 272.

⁴⁾ Beckmann, Journ. f. prakt. Chem. II. 55 (1897), 29.

⁵⁾ Beckmann, Liebig's Annalen 202 (1891), 31; Journ. f. prakt. Chem. II. 55 (1897), 16.

⁶⁾ Beckmann, Journ. f. prakt. Chem. II. 55 (1897), 17.

Menthol crystallizes in colorless needles or prisms which belong to the hexagonal system. It is characterized by its strong, peppermint-like odor and cooling taste.

Of physical constants the following are recorded:

M. p. 42° ; b. p. $211,5^{\circ}$ (736 mm.).¹⁾

M. p. $42,3$; b. p. $212,5$ (corr. 742 mm.); d_4^{20} 0,890 for solid and d_4^{14} 0,8810 for liquified menthol; $[\alpha]_{D_{40}}^{20} = 49,86'$ likewise for molten menthol.²⁾

b. p. $215,5$ (758 mm.); $\alpha_{D_{31}} = 43\ 45'$ for menthol in super-cooled condition.³⁾

M. p. 43 ; $[\alpha]_{D_{20}} = 49,35$ (in 20 p. c. alcoholic solution), $-50,59$ (in 10 p. c. alcoholic solution):⁴⁾ $n_{D_{13}}^{20}$ 1,4479.⁵⁾

According to recent observations, the melting point of perfectly pure menthol lies between $43,5$ and $44,5$.

Menthol is a saturated secondary alcohol. When dehydrated with potassium acid sulphate, zinc chloride, &c., it is converted mainly into the hydrocarbon $C_{10}H_{18}$, *1st-p*-menthene. The compounds obtained by replacing the hydroxy group by halogen are liquid and little characteristic. With hydrogen iodide and phosphorus it is reduced to hexahydrocymene, $C_{10}H_{20}$.⁶⁾ With chromic acid mixture it is oxidized to the corresponding ketone $C_{10}H_{18}O$, menthone.⁷⁾ With potassium permanganate the same oxidation products result that are obtained from the oxidation of menthone, viz., ketomenthylic acid and β -methyladipic acid melting at 88 to 89° . As a result of these oxidation experiments the above-mentioned formula has been assigned to menthol. This formula has been strengthened by the conversion of menthone into 3-chloreymene effected by Jünger and Klages.⁸⁾ That menthol

¹⁾ Arth, Annal. de Chim. et Phys. VI. 7 (1886), 438.

²⁾ Long, Chem. Zentralbl. 1892, II, 525.

³⁾ Power and Kleber, Pharm. Rundschau (New York) 12 (1894), 162; Arch. der Pharm. 212 (1894), 647, 653.

⁴⁾ Beckmann, Liebig's Annalen 250 (1889), 327; Journ. f. prakt. Chem. II. 33 (1897), 15.

⁵⁾ Brühl, Berl. Berichte 21 (1888), 457, table.

⁶⁾ Berkenheim, Berl. Berichte 25 (1892), 688.

⁷⁾ Beckmann, Liebig's Annalen 250 (1889), 325.

⁸⁾ Berl. Berichte 29 (1896), 314.

in the last fractions of the oil of *Eucalyptus Globulus*.¹⁾ Artificially it can be obtained by the action of nitrous acid upon pinylamine acetate or nitrate.²⁾

For the alcohol isolated from eucalyptus oil Wallach records the following constants:

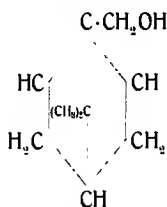
B. p. 92° (12 mm.); $d_{20^{\circ}}$ 0,9745; $n_{D,20^{\circ}}$ 1,49630;

for artificial pinocarveol:

B. p. 215 to 218° ; $d_{22^{\circ}}$ 0,978; $n_{D,20^{\circ}}$ 1,49787.

For its identification the phenylurthane is suited. It melts at 82 to 84° (a small part thereof melts at 95°).

Myrtenol.



Myrtenol, $C_{10}H_{16}O$, is the name applied by v. Soden and Elze³⁾ to an alcohol which they found, mostly as acetic ester, in oil of myrtle.

Its acid phthalic ester melts at 116° from which the alcohol can be regenerated as a colorless oil possessing the odor of myrtle. Its constants are:

B. p. 220 to 221° (751 mm.), $79,5$ to 80° (3,5 mm.); $d_{18^{\circ}}$ 0,985; $\alpha_D + 49^{\circ} 25'$.

Myrtenol has been examined closer by Semmler and Bartelt⁴⁾ who have found the following constants:

B. p. 222 to 224° , $102,5^{\circ}$ (9 mm.); $d_{20^{\circ}}$ 0,9763; $\alpha_D + 45^{\circ} 45'$; n_D 1,49668.

¹⁾ Wallach, *Liebig's Annalen* 346 (1906), 227.

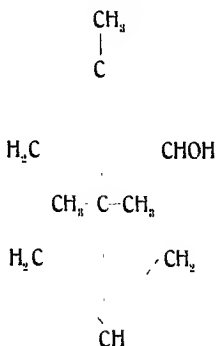
²⁾ Wallach, *Liebig's Annalen* 277 (1893), 149.

³⁾ Chem. Ztg. 29 (1905), 1031.

⁴⁾ Berl. Berichte 40 (1907), 1363.

With phosphorus pentachloride, a chloride $C_{10}H_{15}Cl$ was obtained which upon reduction with alcohol and sodium yielded pinene. The above formula by Semmler and Bartelt is based on these facts. Upon oxidation with chromic acid, the aldehyde myrtenal $C_{10}H_{14}O$ results (b. p. 87 to 90° under 10 mm.; $d_{20} 0.9876$; $n_D 1.50420$). It is further characterized by its semicarbazone, m. p. 230°, and its oxime melting at 71 to 72°. For identification, myrtenol can be either converted into the acid phthalic ester (m. p. 114 to 115°) or oxidized to myrtenal.

Borneol.



As such borneol, $C_{10}H_{16}O$, is found in both optically active modifications, as ester mostly in the *laevogyrate* modification. Borneo camphor from *Dryobalanops Camphora* is *d*-borneol, Ngai camphor (or *Ngai-fên*)¹⁾ from *Blumea balsamifera* consists entirely or in part of *laevogyrate* borneol.

In addition, *d*-borneol has been found in the oils of Siam cardamoms, nutmeg, lavender, rosemary, and spike; *l*-borneol in the oil from the buds of *Pinus maritima*, also in the oils of thuja, citronella, Canada snake root, coriander, yellow pine, valerian, kesso root and feverfew. Furthermore the occurrence of borneol is reported in a number of oils without mention of the direction of rotation, *viz.*, in larch needle oil, in the oil from the needles and cones of *Picea rubens*, in cedar leaf oil, in the

¹⁾ Report of Schimmel & Co. April 1885, 76; April 1900, 147.

oils of ginger, *Piper camphoriferum*, camphor, cinnamon root, sage, thyme, golden rod, and *Achillea nobilis*.

As ester borneol occurs in the oils from the leaves and cones (?) of *Abies alba*, in that of the needles of *Picea excelsa*, the oil of *Pinus montana*, in the German and Swedish oils of *Pinus sylvestris* (?), in the oil of hemlock leaves, in the oils of the needles and cones of *Picea canadensis* and *P. rubens*, in the oils of the needles and twigs of *Larix americana*, in the oil of the twigs of *Abies balsamea*, furthermore in the needle oils of *Picea nigra*, *Abies balsamea*, *Abies sibirica*, *Larix europaea* (?) and *Callitris glauca*; also in the oils of coriander, *Satureja Thymbra*, *Thymus capitatus*, valerian, kesso root and golden rod. As butyrate borneol has been found in valerian oil, and as isovalerate in valerian oil and kesso root oil.

Artificially borneol can be obtained by the reduction of *d*- or *l*-camphor by means of sodium in alcoholic solution¹⁾ or in indifferent solvents.²⁾ However, the borneol thus obtained is never pure since it consists of a mixture of borneol and isoborneol, the latter being probably stereoisomeric with the former. When alcohol is used, less isoborneol is obtained than when indifferent solvents are employed. In the latter case as much as 5 p. c. camphor pinacone is also formed.³⁾ From the mixture of the two borneols, pure borneol can be obtained by converting it into the acetate or benzoate. Upon cooling, the borneol acetate, respectively benzoate crystallizes out and can be saponified. From pinene (turpentine oil) also borneol can be obtained, either as ester by heating with acids, e. g., benzoic acid, oxalic acid, or by converting the pinene into bornylchloride and subsequent change of this compound into borneol or into camphor and isoborneol (see under camphane).

Crystallized from ligroin, pure borneol forms shiny leaflets or plates belonging to the hexagonal system.⁴⁾ It possesses an odor similar to camphor but also reminding of ambra. It melts at 203 to 204° (preparations containing isoborneol melt at 206 to 208°) and boils at 212°. Like camphor, borneol is volatile at

¹⁾ Wallach, Liebig's Annalen 230 (1885), 225.

²⁾ Beckmann, Berl. Berichte 21 (1888), rep. 321.

³⁾ Beckmann, Journ. f. prakt. Chem. II, 55 (1897), 36.

⁴⁾ Traube, Journ. f. prakt. Chem. II, 49 (1894), 3.

ordinary temperature but not to the same degree as the former. According to Plowman,¹⁾ the specific gravity of *d*-borneol is 1.011, that of *l*-borneol 1.02.

The angle of rotation, as found by Beckmann,²⁾ is $+37.44^\circ$ for *d*-borneol. In agreement therewith is the statement by Haller³⁾ who found $[\alpha]_D^{25} +37.63^\circ$ for an alcohol regenerated from the crystallized acetate. For natural *l*-borneol, Beckmann found $[\alpha]_D^{25} -37.74^\circ$,²⁾ Haller $[\alpha]_D^{25} -37.77^\circ$.³⁾ A somewhat higher angle of rotation, *viz.*, $-39^\circ 25'$, was observed for the *l*-borneol known as *Ngai-kén*.⁴⁾ The borneol found in most volatile oils is more or less of a racemic mixture.

The dextrogyrate and lævogyrate modifications of borneol behave alike chemically. Although borneol is a saturated alcohol, it forms unstable addition products with bromine and hydrohalogen⁵⁾ which, however, are not suited for purpose of identification. Hydrohalogens, or better phosphorus halides, also convert borneol into the bornyl halides, which, however, are more satisfactorily prepared from pinene. As a secondary alcohol, borneol upon oxidation is first converted into the corresponding ketone $C_{10}H_{16}O$, camphor. A change in the direction of rotation is not effected thereby. When stronger or acid oxidizing agents are employed, oxidation products of camphor, *viz.*, camphoric acid, or those of camphene may also be produced. Toward dehydrating agents, such as zinc chloride and dilute sulphuric acid, borneol is very stable.⁶⁾ In this respect it behaves very differently from the isomeric *isoborneol*. When treated with phosphorus pentachloride it yields bornylchloride which upon boiling with aniline is converted into camphene.

Numerous ethers and esters of borneol have been prepared. Some of the latter are crystalline and can be utilized for the identification of the borneol. The formate, acetate, valerate and benzoate are described in the chapter on "Esters".

¹⁾ Pharmaceutical Journ. 33 (1874), 711.

²⁾ Liebig's Annalen 250 (1889), 353; Journ. f. prakt. Chem. II. 55 (1897), 33.

³⁾ Compt. rend. 109 (1889), 30; see also Haller, Compt. rend. 112 (1891), 143, On the influence of solvents on the angle of rotation.

⁴⁾ Report of Schimmel & Co. April 1895, 76.

⁵⁾ Wallach, Liebig's Annalen 230 (1885), 226.

⁶⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 8.

By heating borneol with potassium hydroxide to 250 to 280°, Guerbet¹⁾ accomplished an almost quantitative direct change to campholic and *isocampholic* acids.

In order to determine the presence of borncol in volatile oils, fraction 205 to 215° is used. Upon cooling borneol not infrequently crystallizes out.

For its identification the bornylphenylurethane is prepared with the aid of carbanil. It melts at 138 to 139°) and is optically active in the same direction as the underlying borneol. The acetate melting at 29° can also be used, as well as the addition products of borneol with chloral and bromal. That with chloral melts at 55 to 56°,*) that with bromal at 105 to 106°.) Finally, borneol can be oxidized with Beckmann's chromic acid mixture to camphor and the latter identified by means of its oxime which melts at 118 to 119°.

Occasionally it is necessary to separate a mixture of borneol and camphor. In such a case one can proceed according Haller's²⁾ method whereby the mixture is heated with succinic acid anhydride, thus converting the borneol into its acid succinic acid ester, the sodium salt of which is soluble in water and hence can readily be separated from the camphor. In place of succinic acid anhydride, phthalic acid anhydride can be employed. The benzoic and stearic esters of borneol, which can be obtained by heating with the corresponding acid anhydrides, are difficultly volatile. Hence any camphor can be separated from these by steam distillation. On the other hand, camphor can be converted into its oxime and this be separated from the mixture by shaking with 25 p. c. sulphuric acid.

For the quantitative determination of borneol in such a mixture, a very concentrated solution thereof in a suitable solvent (xylene) can be acetylated and the alcohol content ascertained by means of the ester number.

If *isoborneol* be present, this can be converted into camphene by heating with benzoic acid, benzoic acid anhydride or stearic

¹⁾ Compt. rend. 147 (1908), 70; 148 (1909), 98.

²⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 5.

³⁾ Haller, Compt. rend. 112 (1891), 145.

⁴⁾ Minguin, Compt. rend. 116 (1893), 889; Bertram and Walbaum record, *loc. cit.*, 98 to 99°.

⁵⁾ Compt. rend. 108 (1889), 1308.

acid and the borneol regenerated from its ester. By heating for 1 to $1\frac{1}{2}$ hour with a mixture of 20 p. c. sulphuric acid and 80 p. c. methyl alcohol, the *isoborneol* only¹⁾ is converted into the methyl ether. In order to differentiate borneol from *isoborneol* Tschugaeff's method, based on the behavior of nitric acid toward the two alcohols, is well suited.²⁾ With pure concentrated nitric acid, borneol develops red vapors, but pure *isoborneol* never. Oxidizing agents attack borneol more readily. It is also noteworthy that the derivatives of borneol are more difficultly soluble than those of *isoborneol*.

By treating camphene hydrochloride with milk of lime, Aschan³⁾ prepared a new borneol designated *camphene hydrate*. It consists of a hard, white crystalline mass that melts at 142° and boils at 205° . The melting point of the sublimed substance is 150 to 151° . The odor is moldy and menthone-like. Characteristic of the new alcohol is the readiness with which it loses water thus regenerating camphene. The loss of water results even when the alcohol is shaken with warm, dilute mineral acids, or when it is boiled with glacial acetic acid, or sometimes even upon distillation.

Isoborneol.

This alcohol which results together with borneol upon reduction of camphor, and which, according to the latest views, is regarded as stereoisomeric with borneol, can also be obtained upon hydration of camphene.¹⁾ According to Bertram and Walbaum it melts at 212° in the sealed tube. Its boiling point cannot be ascertained since the alcohol begins to sublime before the boiling temperature has been reached. Its phenylurethane melts at 138 to 139° and regenerates *isoborneol* when treated with alcoholic potassa. When heated with dehydrating agents camphene results. The reactions by means of which *isoborneol* can be distinguished from borneol have already been discussed under the latter.

¹⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 8; Hesse, Berl. Berichte 39 (1906), 1144.

²⁾ Chem. Ztg. 26 (1902), 1224.

³⁾ Berl. Berichte 41 (1908), 1092.

⁴⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 1.

Thujyl alcohol.

Thujyl alcohol (tanacetyl alcohol), $C_{10}H_{18}O$, occurs in oil of wormwood, in part as such, in part as esters of acetic, valeric and possibly also of palmitic acids.

Artificially it was obtained by Semmler¹⁾ and by Wallach²⁾ by the reduction of thujone. The constitution of thujone has not yet been definitely ascertained. (Comp. thujone).

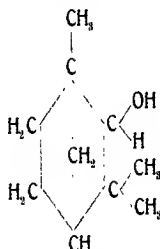
Semmler¹⁾ found:

B. p. 92.5° (13 mm.); d_{20}^4 0.9249; n_D^{20} 1.4635.

Wallach²⁾ has recorded the following constants:

B. p. 210 to 212° ; d_{20}^4 0.9265.

Thujyl alcohol reveals the properties of a secondary alcohol; it is readily oxidized to the ketone thujone. It is this property that is used for its identification. Thujone oxime melts at 54° .

Fenchyl alcohol.

Fenchyl alcohol, to which Semmler has assigned the above formula, has thus far been found but once in a volatile oil,³⁾ namely in the oil obtained by steam distillation from the stumps of the yellow pine or *Pinus palustris* several years after the timber had been cut. Artificially it is obtained by the reduction of fenchone. According to Barbier and Grignard⁴⁾ fenchyl

¹⁾ Berl. Berichte 25 (1892), 3344.

²⁾ Liebig's Annalen 272 (1893), 109.

³⁾ Report of Schimmel & Co. April 1910, 107.

⁴⁾ Bull. Soc. chim. IV. 5 (1909), 512, 519.

alcohol results together with other alcohols when French turpentine oil is hydrated. These investigators assume that it is formed from the β -pinene present, an assumption that has not yet been proven.

Fenchyl alcohol obtained by reduction of fenchone is optically active in an opposite direction from that of the ketone.

Wallach records the following properties:

B. p. 201°; $d_{400} 0.933$; $[\alpha]_D - 10.35^{\circ}$; ¹⁾ m. p. 45°.²⁾

Bertram and Helle³⁾ found:

M. p. 45°; b. p. 201 to 202°; $[\alpha]_D - 10.9^{\circ}$.

The *i*-fenchyl alcohol isolated from yellow pine oil possessed the following constants:

M. p. 33 to 35°; b. p. 202 to 203°; $[\alpha]_D + 0^{\circ}$.

An inactive product obtained by Wallach by mixing *d*- and *i*-fenchyl alcohol had the same melting point.

When oxidized, fenchyl alcohol yields fenchone, when dehydrated, fenchene.

For the identification of active fenchyl alcohol, the acid fenchyl-phthalic acid ester, which melts at 145 to 145.5°, and the phenyl-urethane, which melts at 82 to 82.5°, are used. Of the inactive derivatives the acid phthalic ester melts lower (at 143°) and the phenyl urethane higher (at about 88°) than the corresponding active derivatives. The oxidation to fenchone and the characteristic derivatives of this ketone may be used for identifying fenchyl alcohol.

Corresponding to the aliphatic sesquiterpenes there are oxygenated derivatives found in volatile oils which, judging from their properties, must be regarded as derivatives of this class of sesquiterpenes. While they have been observed but rarely and though but little is known as to their constitution, it is to be expected that a more thorough investigation will reveal their more frequent occurrence.

¹⁾ Liebig's Annalen 263 (1891), 145.

²⁾ Ibidem 284 (1895), 331.

³⁾ Journ. f. prakt. Chem. II. 61 (1900), 295.

ALIPHATIC SESQUITERPENE ALCOHOLS.

Nerolidol, $C_{15}H_{26}O$, has been found in the high-boiling fractions of orange blossom oil.

B. p. 276 to 277°, 128 to 129° (6 mm.); $d_{15} 0.880$; $n_D + 13^\circ 32'.$ ¹⁾

While it itself possesses but a faint odor, it has the capacity to fix other perfumes.

Farnesol, $C_{15}H_{26}O$, occurs as ester in the oil of ambrette seeds, the oil of linden blossoms and in the flower oils of several species of acacia, possibly also in oil of rose.

B. p. 160° (10 mm.); $d_{15} 0.885$; $n_D 1.488.$ ²⁾

B. p. 149° (4 mm.); $d_{15} 0.894$; $n_D + 0^\circ.$ ³⁾

Its odor is faint, reminding of that of cedarwood. Upon oxidation it yields the aldehyde farnesal, $C_{15}H_{24}O$, the semicarbazone of which melts at 133 to 135°.³⁾

More important than the aliphatic are the cyclic sesquiterpene alcohols. As a rule the amount in which they occur in the oils is smaller than that of the sesquiterpenes; though there are oils, like the East Indian sandalwood oil, that consist almost entirely of sesquiterpene alcohols. Many of them are characterized by a marked capacity to crystallize. This is particularly true of the tertiary compounds. Hence they occasionally separate from the oils in crystalline form upon standing. Formerly such separations were designated as "camphor", hence some of the conventional names are still in use.

For the crystalline sesquiterpene alcohols, the melting point serves as a characteristic constant. Their isolation from the volatile oils seldom affords difficulties since they can be separated by crystallization. In order to isolate the liquid sesquiterpene alcohols, fractional distillation has to be resorted to. Under ordinary pressure they distill at about 300°.

Chemically, a distinction is made between primary, secondary, and tertiary sesquiterpene alcohols. From another point of view they can be classified into bicyclic and tricyclic compounds. In

¹⁾ Hesse and Zeitschel, Journ. f. prakt. Chem. II. 66 (1902), 504.

²⁾ Haarmann & Reimer, G. I. P. 149603; Chem. Zentralbl. 1904, I. 975.

³⁾ v. Soden and Treff, Berl. Berichte 37 (1904), 1095.

addition, there are compounds of the formulas $C_{18}H_{24}O$ and $C_{15}H_{20}O$ which stand in very close relation to the sesquiterpene alcohols. But very little is known concerning the constitution of these as of the sesquiterpene alcohols. Herewith there follows a compilation of the representatives of this group that have thus far been found in volatile oils.

DICYCLIC SESQUITERPENE ALCOHOLS.

Santalols, $C_{15}H_{24}O$. The principal component of East Indian sandalwood oil (from *Santalum album*) is a mixture of two primary unsaturated alcohols, which have been designated α - and β -santalol. The former, in all probability, is tricyclic, the latter dicyclic. Quantitatively the α -compound predominates. For two crude santalols Semmler¹⁾ records the following constants:

B. p. 161 to 168° (10 mm.); d_{20}^w 0.973; n_D^{21} 1.50974; d_{18}^w 0.9762; n_D^{18} 1.50974.

v. Soden²⁾ records the following maxima and minima:

d_{18}^w 0.976 to 0.978; n_D^{16} — 16° 30' to — 20°.

In the laboratory of Schimmel & Co. the following constants were observed in connection with crude santalol of their own manufacture:

d_{18}^w 0.973 to 0.982; n_D^{14} — 14° to — 24°; n_{D20}^w 1.504 to 1.509, soluble at 20° in 3 to 4 vols. of 70 p. c. alcohol.

For the two varieties of santalol the following constants have been recorded:

α -Santalol: b. p. 300 to 301° (760 mm.); 162 to 163° (13 mm.); d_w 0.9854; n_D^{12} — 1.2°.³⁾

B. p. 301 to 302° (752 mm.), 155° (8 mm.); d_{15}^w 0.977;⁴⁾

β -Santalol: b. p. 309 to 310° (760 mm.), 170 to 171° (14 mm.); d_w 0.9868; n_D^{10} — 56°.⁵⁾

¹⁾ Berl. Berichte 40 (1907), 1132.

²⁾ Pharm. Ztg. 54 (1909), 251.

³⁾ Guerbet, Compt. rend. 130 (1900), 1326.

⁴⁾ v. Soden, Arch. der Pharm. 288 (1900), 362.

⁵⁾ Guerbet, *loc. cit.*

Concerning its chemical properties, santalol has been examined thoroughly by a number of investigators. Hence a large number of derivatives is known. Upon oxidation with chromic acid, the aldehyde santalal, $C_{15}H_{22}O$, results, the semicarbazone of which melts at 230° .¹⁾ Oxidation with permanganate in acetone solution converts it mainly into tricycllocksantallic acid, $C_{11}H_{16}O_2$, m. p. 71 to 72° .²⁾

The other derivatives are scarcely suited for identification purposes, hence are not mentioned in this connection.

It should be mentioned, however, that santalal also is possibly a constituent of East Indian sandalwood oil.

A so-called santal camphor, a compound $C_{15}H_{24}O_2$ has been separated from the oil of a South Australian sandalwood (*Santalum Preissianum*). It melts at 104 to 105° .³⁾

Amyrols, $C_{15}H_{24}O$ and $C_{15}H_{26}O$, were obtained from the West Indian sandalwood oil distilled from *Amyris* species. They apparently constitute mixtures of compounds possessing the above formulas. Upon esterification, dehydration is apt to take place.

Betulol, $C_{15}H_{24}O$, occurs free and as acetate in the oil of birch buds. B. p. 284 to 288° (743 mm.); 138 to 140° (4 mm.); $d_{15} 0.975$; $n_D - 35^{\circ}$; n_D abt. 1.50179 . It can be esterified quantitatively.

TRICYCLIC SESQUITERPENE ALCOHOLS.

Cedrol (cedar camphor, cypress camphor), $C_{15}H_{26}O$, has been found in oils of cedarwood (*Juniperus virginiana*), *Juniperus chinensis* (?), cypress and *Origanum smyrnæum* (?) as the dextrogyrate modification. M. p. 86 to 87° ; b. p. 291 to 294° (ord. pressure), 157 to 160° (8 mm.); $[\alpha]_D + 9.31'$ (in chloroform solution). Treated with phosphorus pentoxide or formic acid, it readily splits off water, yielding cedrene. The phenylurethane melts at 106 to 107° .⁴⁾

¹⁾ Semmler and Bode, Berl. Berichte 40 (1907), 1126.

²⁾ Ibidem 1133.

³⁾ Report of Schimmel & Co. April 1891, 65; October 1891, 45.

⁴⁾ Report of Schimmel & Co. October 1906, 49; April 1910, 46.

Cubeb camphor, $C_{16}H_{26}O$, is reported to separate from oil of cubeb when the latter is exposed to the air for a long period. It is lævogyrate, melts at 68 to 70° and boils at 248° with loss of water. This loss of water can also be brought about readily by other means.

Ledum camphor, $C_{16}H_{26}O$, has been obtained from the oil of Labrador tea in long, colorless needle-like prisms, melting at 104° and boiling at 281°. Its alcoholic solution is slightly dextrogyrate. It produces a toxic effect on the human organism. It is readily converted into the sesquiterpene ledene.

Patchouli alcohol or *-camphor*, $C_{15}H_{26}O$, is an odorless constituent of patchouli oil from which it separates in crystals that melt at 56°. It is strongly lævogyrate, $[\alpha]_D^{20} - 97.42'$ (in chloroformic solution). Like a liquid compound from the same oil, which however deviates the angle of polarized light to a lesser degree, it readily loses water, forming patchoulene.

Atractylol, $C_{15}H_{26}O$, separates from the oil distilled from the roots of *Atractylis ovata*. M. p. 59°; b. p. 290 to 292° (760 mm.); 162° (15 mm.); n_D^{20} 1.51029 to 1.51101. It is distinguished from patchouli alcohol by being optically inactive. The odor is said to remind of that of lillies of the valley. If a few drops of sulphuric acid be added to a chloroform solution, a red-brown color is produced changing to violet. This alcohol also readily loses water yielding atractylene.

Guajol, $C_{15}H_{26}O$. This sesquiterpene alcohol is contained in the oil of the wood of *Bulnesia Sarmienti* and in that obtained from the wood known as "*Kajoe garoe*".¹⁾ Its properties are:

M. p. 91°; b. p. 288°; $n_D^{20} - 29.8'$.

The properties of the compound obtained from *Kajoe garoe* deviate somewhat. Guajol does not lose water as readily as do some of the other sesquiterpene alcohols. When water is split off it yields the blue-colored guajene.

¹⁾ Eyken, Recueil des trav. chim. des P.-B. 25 (1906), 40, 44; Chem. Zentralbl. 1906, I. 841.

For guajyl methyl ether, obtained by the action of methyl iodide on guajol potassium, Gandurin¹⁾ found the following constants:

B.p. 141 to 143° (9 mm.); d_4^{20} 0.9513; d_4^{25} 0.9332; $[\alpha]_{D^{20}}$ —31.81°; $n_{D^{20}}$ 1.48963.

Matico camphor, $C_{15}H_{26}O$, formerly obtained from the oil of matico leaves, is no longer found in this material. It crystallizes in thick, hexagonal columns melting at 94°; $[\alpha]_D$ —28.73° in chloroform solution. It loses water when heated for several hours with 50 p. c. sulphuric acid.

Sesquiterpene alcohol from eucalyptus oil. From the oil of *Eucalyptus Globulus* a sesquiterpene alcohol $C_{15}H_{26}O$ of the following properties has been isolated:

M. p. 88.5°; h. p. 283° (755 mm.); $[\alpha]_D$ —35°29' (in chloroform solution).

When water is split off, two distinct sesquiterpenes are formed.

There can be no doubt that sesquiterpene alcohols are widely distributed in volatile oils. A number of compounds have been isolated which evidently belong to this group. Thus from oil of juniper berries a substance melting at 165 to 166°, from ylang-ylang oil one melting at 138°, and from the oil of *Piper Lowong* one melting at 164°. So far as the present stage of investigation seems to indicate, the presence of sesquiterpene alcohols may be suspected in the oils of Atlas cedar, *Cryptomeria japonica*, victiver, paradisc grains, paracoto bark, *Nectandra Caparrapi*, Maali resin, laurel leaves, camphor, copaiba balsam, pelargonium, neroli, angostura bark, opopanax resin, cascarilla, *Aralia nudicaulis*, asafetida, valcrian, Spanish hops, and *Blumea balsamifera*.

In this connection several alcoholic constituents of volatile oils with more than 15 carbon atoms in the molecule should be mentioned:

Turmerol, $C_{19}H_{34}O$, contained in oil of turmeric (b. p. 285 to 290°; d_{17} 0.9016; $[\alpha]_D$ +33.52°); and an

¹⁾ Berl. Berichte 41 (1908), 4362.

Alcohol, $C_{20}H_{32}O$, isolated from the oil of *Erythroxylon monogynum* (m. p. 117 to 118°; $[\alpha]_D + 32^{\circ}28'$ in chloroform solution). This alcohol can be esterified quantitatively, the acetate melting at 72 to 73°.

The fact that the sesquiterpene fractions of certain oils are colored blue should not fail to receive mention. This blue color is most intense in the fractions boiling between 275 to 300°, though also observable in the lower fractions. The color varies from the most intense indigo-blue to greenish shades. As is the case with chamomile oil, the oil itself may be colored strongly blue. Certain oils obtained by the dry distillation of resins reveal a similar color, as do also some of the sesquiterpenes obtained artificially (guaiane, atractylene). As to the cause of the color not the least is known. There would appear to be some indication, however, that it is due to the formation of oxidation products. The following list contains the names of those oils in which the blue color has been observed, viz., the oil of *Piper Lowong*, the oil from the berries of *Piper Cubeba*, the oil of Canada snake root, camphor oil, the oil of picurium beans, Réunion geranium oil, the oils of guaiac resin, cedrella wood, damiana leaves, *Aralia nudicaulis*, *Meum athamanticum*, the root of *Pimpinella nigra*, Japanese angelica root, asafetida, galbanum resin, sumbul root, opopanax resin, patchouli, dilem leaves, valerian, kesso root, chamomile, wormwood, milfoil, European pennyroyal, Roman chamomile, *Achillea coronopifolia*, *A. inoschata*, and eleccampane.

ALDEHYDES.

ALIPHATIC ALDEHYDES.

Aside from the aldehydes citral and citronellal, which are to be mentioned later in this chapter and which occur rather frequently, the aliphatic aldehydes constitute only minor constituents of the volatile oils. In as much, however, as the charac-

teristic odor of some oils is dependent on the presence of small amounts of these aldehydes, they are, nevertheless, of great importance. Because of this property, such aldehydes as nonyllic aldehyde and decylic aldehyde, play an important role in the production of synthetic oils.

Like the corresponding alcohols, the lower members of this series, which are probably formed during the process of steam distillation, are found principally in the aqueous distillate or in the first distillate obtained during the fractionation of the oil. Their presence is frequently revealed by their pungent odor. They are most readily isolated by means of bisulphite. Lower aldehydes are contained in the oils of ginger, kassia root, sabbadilla, *Allium ursinum*, milfoil, *Eucalyptus Globulus*. In the following account brief mention is made of the aldehydes thus far found in volatile oils.

Formaldehyde, $\text{H} \cdot \text{CHO}$, has thus far been identified with certainty in apopin oil. For its identification, the liquid, in which its presence is suspected, is evaporated with ammonia on a water bath. If present, the characteristic crystals of hexamethylene tetramine are formed.

Acetaldehyde, $\text{CH}_3 \cdot \text{CHO}$, has been observed rather frequently, more particularly in seed oils. It has been found in the oils of orris, camphor, anise, caraway, rosemary (?) and peppermint, especially when working with larger amounts of these oils. It is identified by means of the color reaction¹⁾ with trimethylamine and sodium nitroprusside.

Butyric aldehyde, $\text{C}_3\text{H}_7 \cdot \text{CHO}$, boils at 75° and presumably occurs in the oils of *Eucalyptus Globulus* and cajeput. It can be identified by means of its *p*-nitrophenylhydrazone²⁾ which melts at 91 to 92° .

Isovaleric aldehyde, $\text{C}_4\text{H}_9 \cdot \text{CHO}$, can frequently be recognized by its disagreeable, irritating odor which causes

¹⁾ Rimini, Annali Farmacoterapia e Ch. 1898, 249; Chem. Zentralbl. 1898, II. 277.

²⁾ Dakin, Journ. of Biol. Chem. 4 (1908), 235; Chem. Zentralbl. 1908, I. 1259.

coughing. It possibly occurs in the oils of cajuput, niaouli, *Eucalyptus rostrata*, *E. Globulus*, and cloves. In addition isovaleric aldehyde has been found in American and French peppermint oil, in kesso oil (?), and in lavender oil (?). It can be characterized by its oxidation to isovaleric acid. Isovaleric aldehyde boils at 92°. Its thioscmicarbazone melts at 52 to 53°.¹)

Capronic aldehyde, $C_6H_{11}\cdot CHO$, boils at 128° and is very likely contained in the oil of *Eucalyptus Globulus*. The unpleasant, irritating odor of several eucalyptus oils is probably due to the presence of this aldehyde as well as that of butyric and valeric aldehydes.²)

n-Octylic aldehyde, $C_8H_{17}\cdot CHO$, is possibly contained in lemon oil. It possesses a strong odor reminding of cœnanthol. The following properties were ascertained by Schimmel & Co.³) in connection with a preparation obtained by the oxidation of octylic alcohol and purified through the bisulphite compound:

B. p. 60 to 63° (10 mm.); d_{15}^4 , 0,827.

Schmmler⁴) records the following constants:

B. p. 60 to 61° (9 mm.); d_{20}^4 , 0,8211; n_D^{20} , 1,41955; b. p. of the oxime 60°; m. p. of the semicarbazone 101°.

Octyl- β -naphthocinchoninic acid forms small, white crystals which melt at 234°. With phosphonium iodide, octylic aldehyde combines to a compound that melts at 115,5°.

n-Nonylic aldehyde, $C_9H_{17}\cdot CHO$, is a constituent of the oil of orris root, of Ceylon cinnamon oil, of German rose oil, of mandarin oil, and probably also of lemon oil. The following constants have been observed in connection with an aldehyde isolated from oil of rose:

B. p. 80 to 82° (13 mm.), d_{15}^4 , 0,8277; n_D^{15} , 1,42452.⁵)

¹) Neuberg and Neimann, Berl. Berichte 35 (1902), 2052.

²) Schimmel's Bericht April 1888, 18.

³) Report of Schimmel & Co. April 1899, 2b.

⁴) Berl. Berichte 42 (1909), 1161.

⁵) Report of Schimmel & Co. October 1900, 54.

Upon oxidation it yields pelargonic acid which boils at 252 to 253°. The aldehyde is characterized by its oxime which melts at 69° and by its semicarbazone which melts at 100°.

n-Decylic aldehyde, $C_9H_{18} \cdot CHO$, occurs in the oils of lemongrass, orris root, sweet orange, mandarin, neroli, cassie blossoms, and coriander. Furthermore, its presence in the leaf oil of *Abies alba* seems probable. Stephan¹⁾ records the following constants for a decylic aldehyde isolated from oil of sweet orange:

B. p. 207 to 209° (755 mm.) with slight decomposition, 93 to 94° (12 mm.); d_{15}^4 0,828; $n_{D,15}^{20}$ 1,42977.

For decylic aldehyde from lemongrass oil the following constants were observed:

B. p. 80 to 81° (6,5 mm.); d_{15}^4 0,8361.²⁾

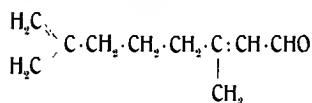
Characteristic are the naphthocinchoninic derivative, obtained by condensation of the aldehyde with β -naphthylamine and pyrotartaric acid, and which melts at 237°; the oxime, which melts at 69°; the semicarbazone, which melts at 102°; and the *n*-capric acid, which results upon oxidation and which melts at 30 to 31° and boils at 267 to 269° (753 mm).

Laurinic aldehyde, $C_{11}H_{22} \cdot CHO$, occurs in the leaf oil of *Abies alba* and possibly also in oil of rue. At ordinary temperature it is solid. Exposed to air it oxidizes to laurinic acid which melts at 43°. The semicarbazone melts at 101,5 to 102,5°.

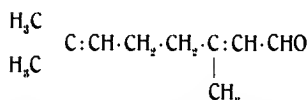
Of much greater importance than the aldehydes thus far enumerated are the aliphatic terpene aldehydes citral, $C_{10}H_{16}O$, and citronellal, $C_{10}H_{18}O$; also a number of aromatic aldehydes. The former are especially noteworthy because of their relation to other volatile oil constituents, more particularly the alcohols. Of the latter, benzaldehyde and cinnamic aldehyde occur in considerable amounts in some oils.

¹⁾ Journ. f. prakt. Chem. II. 62 (1900), 525.

²⁾ Report of Schimmel & Co. October 1905, 45.

Citral.

or



Citral¹⁾ is the only aliphatic aldehyde of the formula C₁₀H₁₆O that has thus far been isolated from volatile oils. It is also known as geranial, because of its close relation to geraniol, being the first oxidation product of the latter. Its occurrence in nature is rather common. It was first found by J. Bertram²⁾ in the oil of *Baekhousia citriodora*. In as much as it was shown to be identical with the lemon-scented constituent of oil of lemon, it was named citral. Larger amounts are contained in the lemon-grass oil as well as in the *Baekhousia* oil just referred to. It occurs also in Java citronella oil, ginger oil, kobushi oil, sassafras leaf oil, Japanese cinnamon oil, the oils from the fruit, bark and leaves respectively of *Tetranthera citrata*, German rose oil, the oils from the leaves and twigs of the sweet orange tree and the lemon tree, cedro oil, West-Indian limette oil, mandarin oil, oil of sweet orange (?), Japanese pepper oil, may oil, oil of bay, oil of pimenta, the oils of *Eucalyptus patentinervis*, *E. Staigeriana*, *E. vitrea* (?), *Leptospermum Liversidgei*, verbena, *Monarda citriodora*, and melissa. In these oils citral occurs in two modifications, designated citral "a" and citral "b", which appear to be stereoisomeric.³⁾ In practically all cases citral "a" predominates.

From all of the oils enumerated above, citral can be isolated by means of its crystalline addition product with bisulphite (see below). From this compound, after previous purification by washing with alcohol and ether, citral can be obtained in a pure state by decomposition with alkali carbonate.

¹⁾ Concerning the history of citral see Tiemann, Berl. Berichte 31 (1898), 3278.

²⁾ Schimmel's Bericht October 1888, 17.

³⁾ Tiemann, Berl. Berichte 33 (1900), 877.

To the extent of 30 to 40 p. c. yield citral can be obtained artificially by the oxidation of geraniol with chromic acid mixture.¹⁾ In like manner the tertiary alcohol linalool (likewise nerol) yields the same oxidation product, since the acid oxidizing agent first causes the rearrangement of linalool to geraniol. Synthetically, citral has been obtained by the distillation of the calcium salt of geranic acid with calcium formate.²⁾

Citral is a thin, light yellow liquid, which is optically inactive and which possesses a penetrating odor of lemon. Under atmospheric pressure it distils at 228 to 229° with slight decomposition. Its constants, as recorded by Tiemann and Semmler,³⁾ are as follows:

B. p. 110 to 112° (12 mm.); 117 to 119° (20 mm.); 120 to 122° (23 mm.); d_{15}° 0,8972; n_D 1,4931; d_{20}° 0,8844; n_D 1,48611.

In addition Tiemann⁴⁾ records the following constants:

For citral "a": B. p. 118 to 119° (20 mm.); d_{20}° 0,8898; n_D 1,4891.

For citral "b": B. p. 117 to 118° (20 mm.); d_{20}° 0,8888; n_D 1,49001.

In the laboratory of Schimmel & Co. the following observations have been made in connection with citral carefully purified through the bisulphite or the hydrosulphonic acid addition products:

For citral from lemongrass oil:

B. p. 110 to 111° (12 mm.); d_{15}° 0,893; n_{D17}° 1,49015.⁵⁾

For citral from lemon oil:

B. p. 92 to 93° (5 mm.); d_{15}° 0,8926; n_{D20}° 1,48853.

For citral from the oil of the fruits of *Tetranthera citrata*:

d_{15}° 0,8941; n_{D20}° 1,8767.

Commercial products prepared by Schimmel & Co. had the following properties:

d_{15}° 0,892 to 0,895; n_{D20}° 1,488 to 1,489; soluble in about 7 vols. of 60 p. c. alcohol.

¹⁾ Tiemann, Berl. Berichte 31 (1898), 3311.

²⁾ Tiemann, Berl. Berichte 31 (1898), 827.

³⁾ Berl. Berichte 26 (1893), 2709.

⁴⁾ Berl. Berichte 32 (1899), 117, 120; 33 (1900), 880.

⁵⁾ Report of Schimmel & Co. April 1899, 64.

As diolefinic aldehyde citral adds two molecules of bromine, but does not yield a solid bromide. Toward acids and acid reagents it is very susceptible, being altered materially by them. Like many of its derivatives, it can readily be converted into cyclic compounds. Dilute sulphuric acid and potassium acid sulphate act very energetically with the formation of cymene.¹⁾ Alkalies likewise attack citral. When boiled with potassium carbonate solution it is broken up into acetaldehyde and methylheptenone, $C_8H_{14}O$.²⁾ The same ketone results upon the oxidation of citral and is found accompanying the citral in lemongrass oil (see also under "Ketones").

Citral reveals all of the properties of an aldehyde. It reacts with the well-known reagents for aldehydes and when reduced with sodium amalgam in acetic acid solution it is converted into geraniol.³⁾ Toward sodium acid sulphite solution it behaves in a peculiar manner.⁴⁾ If the solution does not contain too large amounts of free sulphurous acid, the difficultly soluble, normal crystalline addition product, $C_{10}H_{16} \cdot CH(OH)SO_3Na$, is formed when the aldehyde is shaken with such a solution. From this compound sodium carbonate and sodium hydroxide regenerate the citral, but not quantitatively. If, however, this crystalline addition product is gently heated with an excess of bisulphite solution, it is dissolved with the formation of a "labile" dihydrodisulphonic acid derivative of citral, $C_{10}H_{16} \cdot (SO_3Na)_2 \cdot CHO$. From this the citral can be regenerated no longer by means of alkali carbonate, but by means of caustic alkali. If, however, the temperature is allowed to rise too high, the "labile" compound has been changed to a "stable" dihydrodisulphonic acid derivative, which is no longer yields citral even when acted upon with caustic alkali. This same compound results likewise when the normal compound is suspended in water and subjected to the action of steam until it has gone into solution. If the solution of the "labile" citral dihydrosulphonate of sodium is shaken with citral,

¹⁾ Semmler, Berl. Berichte 24 (1891), 204.

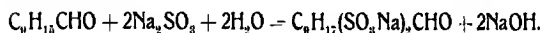
²⁾ Verley, Bull. Soc. chim. III. 17 (1897), 175; Tiemann, Berl. Berichte 32 (1899), 107.

³⁾ Tiemann, Berl. Berichte 31 (1898), 828.

⁴⁾ Tiemann and Semmler, Berl. Berichte 26 (1893), 2708; Tiemann, Berl. Berichte 31 (1898), 3310.

it is changed back to the citral hydromonosulphonate of sodium, $C_{10}H_{16}(SO_3Na) \cdot CHO$.

The "labile" citral dihydrodisulphonate of sodium results likewise when an aqueous solution of sodium sulphite is shaken with citral:



In as much as the sodium hydroxide set free would regenerate the citral from the compound just formed, it must be combined with dilute acetic acid, sulphuric acid, or an acid salt such as sodium bisulphite or sodium bicarbonate. According to Tiemann,¹⁾ the following method may be followed: A solution of 350 g. of sodium sulphite, $Na_2SO_3 + 7H_2O$, in 1 liter of water, colored red with a little phenolphthalein solution, is shaken with 100 g. of pure citral. The strongly alkaline reaction produced is reduced from time to time by the gradual addition of a standardized sulphuric acid of about 20 p. c. strength. The solution should always be slightly alkaline as revealed by the red color of the indicator. Otherwise the normal sodium acid sulphite addition product of citral, which is difficultly soluble, is exclusively formed and separated.

Inasmuch as the derivatives of citral with hydroxylamine, phenylhydrazine, and ammonia are liquid, they cannot be utilized for the characterization of citral. When dehydrated with the aid of acetic acid anhydride, the oxime is converted into the nitrile of geranic acid. When acted upon by semicarbazide, citral yields several well crystallizable semicarbazones.²⁾ Under certain conditions³⁾ this mixture of semicarbazones can be resolved into two compounds melting at 164° and 171° respectively. Hence these can be utilized for the identification of citral. (See below.)

Moderate oxidation, e. g. with silver oxide in ammoniacal solution yields the liquid geranic acid $C_{10}H_{18}O$,⁴⁾ the odor of which resembles that of the higher fatty acids. More energetic oxidation with chromic acid mixture yields methylheptenone which, upon

¹⁾ Berl. Berichte 31 (1898), 3317.

²⁾ Wallach, Berl. Berichte 28 (1895), 1957; Tiemann and Semmler, *ibidem* 2133; Tiemann, Berl. Berichte 31 (1898), 821, 2315.

³⁾ Tiemann, Berl. Berichte 31 (1898), 3331.

⁴⁾ Semmler, Berl. Berichte 28 (1890), 3555; 24 (1891), 203.

further oxidation with potassium permanganate and chromic acid mixture, breaks up into acetone and laevulinic acid.¹⁾ Because of these results the above-mentioned formula, corresponding to that for geraniol, has been assigned to citral. This formula agrees well with the properties of citral.

When condensed with acetone, citral yields a ketone $C_{13}H_{20}O$, pseudoionone. When heated with dilute sulphuric acid, this ketone yields ionone which is isomeric with the irone of orris oil. (See under Ionone.)

Inasmuch as citral possesses a penetrating odor, this will as a rule indicate its presence in volatile oils. For its positive identification, the aldehyde is separated by means of its solid acid sulphite derivative. Regenerated, it is then converted into the α -citryl- β -naphthocinchonic acid, discovered by Doebner,²⁾ by condensation with pyrotartaric acid and β -naphthylamine. For the preparation of this compound, Doebner has given the following directions: 20 g. of pyrotartaric acid and 20 g. of citral (or of the corresponding oil) are dissolved in absolute alcohol. To this solution, 20 g. of β -naphthylamine, likewise dissolved in absolute alcohol, are added and the mixture heated for three hours on a waterbath, the flask being connected with a reflux condenser. Upon cooling, the citrylnaphthocinchonic acid, which has separated in a crystalline form, is separated by filtration and purified by washing with ether. If the acid is very impure, it is dissolved in ammonia and precipitated from the filtered ammoniacal solution by means of acetic acid. The substance thus purified crystallizes from alcohol in yellow laminae. Doebner³⁾ gives the melting point at 197°. However, it lies somewhat higher being found at 200° or even slightly above that temperature.

It should be remembered, however, that, in the presence of but small amounts of citral or other aldehydes, α -methyl- β -naphthocinchonic acid is formed by the interaction of pyrotartaric acid and β -naphthylamine. This acid melts at 310° and is less soluble in alcohol than is citrylnaphthocinchonic acid. Hence it remains in the residue when the crude naphthocinchonic acid is extracted with hot alcohol.

¹⁾ Tiemann and Semmler, Berl. Berichte 26 (1893), 2718.

²⁾ Berl. Berichte 87 (1894), 354, 2026.

³⁾ Loc. cit.; Berl. Berichte 31 (1898), 1891; Comp. *ibidem* 3197, 3327.

It should further be remembered that when other aldehydes are present the corresponding naphthocinchoninic acids are formed. Thus Doebner found not only citryl- but also citronellyl- β -naphthocinchoninic acid (m. p. 225°) in fractions of lemon oil.

As already pointed out, natural citral apparently consists of two stereoisomeric forms, which have been designated citral "a" and citral "b" by Tiemann. The semicarbazone melting at 164° corresponds to the former and can be prepared in accordance with the following directions:

To a solution of 5 parts of citral (or of the fraction to be tested) in 30 parts of glacial acetic acid, a solution of 4 parts of semicarbazide hydrochloride in a little water is added. After standing for a short time, a considerable quantity of semicarbazone separates in needle-like crystals. After having been recrystallised two or three times from methyl alcohol, they melt at 164°. From the mother liquid of this semicarbazone, the semicarbazone corresponding to citral "b" and melting at 171° can be separated.¹⁾ Mixtures of both semicarbazones reveal melting points varying from 130 to 171°. As related compounds, the thiosemicarbazone, melting at 107 to 108°, and the semioxamazone, melting at 190 to 191°, should be mentioned.

Citrylidene cyanacetic acid, $C_9H_{15}\cdot CH:C(CN)\cdot COOH$, obtained by condensation of citral with cyanacetic acid, is another derivative melting at 122° that crystallizes well and hence can be used for the identification of citral. It can be prepared according to the following directions: To a solution of one molecule of cyanacetic acid in three times its weight of water, two molecules of sodium hydroxide (as 30 p. c. sodium hydroxide solution) and one molecule of citral are added. If the citral be pure, it will dissolve without turbidity upon shaking. If the solution be turbid it is shaken out with ether. From the clear solution the citrylidene cyanacetic acid is precipitated by means of acids. It separates either in crystalline form or as an oil that readily congeals. Recrystallized from the benzene solution to which ligroin has been added, it is obtained in short, yellow crystals.²⁾

¹⁾ Tiemann, Berl. Berichte 31 (1898), 3331; 32 (1899), 115; 33 (1900), 877.

²⁾ Tiemann, Berl. Berichte 31 (1898), 3329.

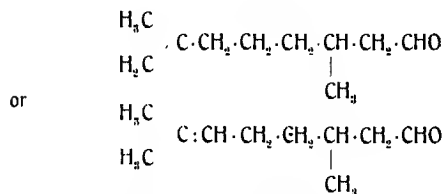
In as much as citral "b" condenses more slowly than does citral "a", this method can be utilized for the separation of both modifications. Citrylidene cyanacetic acid "a" melts at 122°, the "b"-variety at 94 to 95°.)

Still another solid condensation product of citral is obtained with acetyl acetone. It is obtained by condensing 15.2 g. citral and 20 g. of acetyl acetone at room temperature with the aid of piperidine. After standing for three days the entire reaction mass congeals to a crystalline magma. Recrystallized from a mixture of alcohol, ether and ligroin, citrylidene bisacetyl-acetone is obtained in light yellow wart-like crystals that melt at 46 to 48°.)

Tiemann¹⁾ recommended that the presence of citral be established by condensing it with acetone to pseudo ionone and by identifying this by means of its semicarbazone. This method, however, is more complicated than the preparation of citryl naphthocinchoninic acid which is, therefore, given the preference.

A method for effecting the separation of citral, citronellal, and methylheptenone is given under the two last-mentioned compounds.

Citronellal.



The second aliphatic terpene aldehyde with ten carbon atoms that is found in volatile oils is the citronellal, $\text{C}_{10}\text{H}_{18}\text{O}$. It occurs occasionally as companion to citral, of which it is the dihydro-derivative. Differing from citral, citronellal is optically active. However, with but one exception, it has been found in the dextro-

¹⁾ Tiemann, Berl. Berichte **33** (1900), 880.

²⁾ K. Wedemeyer, *Über Kondensationen mittelst aromatischer Basen usw.* Inaug. Dissert. Heidelberg 1897. p. 24.

³⁾ Berl. Berichte **31** (1898), 822.

gyrate modification only. It is probable that whenever citronellal is found with a low angle of rotation it is a mixture of both active modifications.

d-Citronellal has been found in citronella oil, in the oils of *Barosma pulchellum*, *Eucalyptus maculata* var. *citriodora*, *E. dealbata*, and of balm; *l*-citronellal in "Java lemon olie". With certainty the presence of citronellal has been ascertained in the oil from the bark of *Tetranthera polyantha* var. *citrata*, but its angle of rotation has not been recorded. Its presence in oil of lemon and in mandarin oil is still doubtful.

In as much as citronellal can be separated by means of its crystalline bisulphite compound, its isolation from oils containing a large percentage of aldehyde, such as citronella oil and oil of *Eucalyptus maculata*, offers no difficulties. Since citronellal is very susceptible towards acids as well as toward alkalis, alkali carbonate is used to decompose the bisulphite compound. Artificially citronellal has been obtained upon oxidation of the primary alcohol citronellol $C_{10}H_{20}O$; however, the yield is even smaller than when geraniol is oxidized to citral. In this manner the *l*-citronellol from rose oil is converted into *l*-citronellal, which has been designated rhodinal by Bouveault.

Upon the ring cleavage of menthoxime to aliphatic compounds Wallach obtained an aldehyde $C_{10}H_{18}O$ which he designated "Menthocitronellal", and which closely resembles the natural citronellal, but is not identical with the latter.¹⁾

According to Tiemann and Schmidt²⁾ citronellal boils at 205 to 208° under atmospheric pressure and at 103 to 105° under a pressure of 25 mm.; $d_{17.5}^{20}$ 0.8538; n_D^{20} 1.4481; mol. refr. 48.29, computed for $C_{10}H_{18}O$ 47.92.

For a citronellal regenerated from a recrystallized sodium acid sulphite double compound, Tiemann³⁾ records the following constants:

B. p. 203 to 204°; 89 to 91° (14 mm.); $d_{17.8}^{20}$ 0.8554; n_D^{20} 1.4461; mol. refr. 48.00.

¹⁾ Liebig's Annalen 274 (1894), 317; 296 (1897), 131.

²⁾ Berl. Berichte 29 (1896), 905.

³⁾ Berl. Berichte 32 (1899), 818.

As angle of rotation, Kremers¹⁾ recorded $[\alpha]_D + 8,18^\circ$. Later $[\alpha]_D + 12\ 30'$ was observed for a preparation purified by means of its acid sulphite derivative.²⁾

In the laboratory of Schimmel & Co. the following constants were observed in connection with products obtained on a commercial scale:

B. p. 205 to 208° (ord. pressure); 72 to 73° (4,5 mm.); d_{15} , 0,855 to 0,860; $n_D + 10$ to $+ 11$; n_{D20} , 1,444 to 1,449; soluble in 5 to 6 vols. of 70 p. c. alcohol.

Citronellal isolated from "Java lemon oil" revealed the following properties:

B. p. 205 to 208°; d_{15} , 0,8567; $n_D - 3$; n_{D20} , 1,44791.³⁾

Citronellal is an unsaturated aldehyde with one double bond. When reduced in alcoholic solution, that is kept slightly acid by the addition of acetic acid, with sodium amalgam it is converted into the primary alcohol citronellol, $C_{10}H_{20}O$.⁴⁾ Like citral, citronellal is very susceptible toward alkalis and acids. Whereas citral is broken up into acetaldehyde and methylheptanone when treated with alkali, citronellal resinifies. In contact with acids citral loses the elements of a molecule of water and yields cymene; whereas citronellal is converted into an isomeric compound, the *isopulegol*⁵⁾ $C_{10}H_{18}O$ (comp. p. 386). This alcohol, which is likewise isomeric with pulegol, is obtained upon reduction of pulegone, and can be oxidized to the ketone *isopulegone*, $C_{10}H_{16}O$, which can be inverted to natural pulegone. According to Harries and Rodder,⁶⁾ the semicarbazones of *isopulegone* melt at 173° (α -modification) and 183° (β -modification). This ring-formation of citronellal to *isopulegone* takes place very readily, so that commercial citronellal, at least when purified through the bisulphite compound, always contains *isopulegol*.⁷⁾

¹⁾ Americ. chem. Journ. 14 (1892), 203.

²⁾ Tiemann and Schmidt, *loc. cit.*

³⁾ Report of Schimmel & Co. April 1903, 22.

⁴⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 906.

⁵⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 913; 30 (1897), 22.

⁶⁾ Berl. Berichte 32 (1899), 3367.

⁷⁾ Tiemann, Berl. Berichte 32 (1899), 825; Labbé, Bull. Soc. chim. III. 21 (1899), 1023.

The change to *isopulegol* can also be utilized for the quantitative determination of citronellal. For this purpose compare the chapter "The examination of volatile oils".

Toward sodium acid sulphite, citronellal behaves similar to citral. In addition to the crystalline normal double compound with one molecule of NaHSO_3 , in which the bisulphite has been added to the aldehyde group, it also yields hydrosulphonic acid derivatives with one or two molecules of NaHSO_3 . In these latter compounds the sodium acid sulphite molecule is added to the double linkage between carbon and carbon. However, if two molecules are added, one must necessarily add to the aldehyde group, there being but one double linkage between carbon and carbon.¹⁾ It is from the first-mentioned compound only that citronellal can be regenerated, whereas it cannot be regenerated from the hydrosulphonic acid derivatives by either sodium carbonate or alkali hydrate. With neutral sulphite, citronellal likewise reacts with the formation of a non-decomposable hydrosulphonic acid derivative. However, the reaction then only takes place when a strong current of carbon dioxide is passed into the mixture or if a sufficient amount of some other acid is added. This behavior of citronellal can be utilized for its separation from citral, which combines with neutral sulphite without addition of acid. Care must be taken, however, to neutralize the sodium hydroxide as it is liberated.

Another method of separation is based on the property of the citronellal to combine only with a concentrated solution of sodium sulphite and sodium bicarbonate, whereas citral also combines with dilute solutions.²⁾

Since methylheptenone does not combine with even a concentrated solution of sodium sulphite and sodium bicarbonate, this reagent also serves as a means to separate citronellal from any admixture of methylheptenone.³⁾

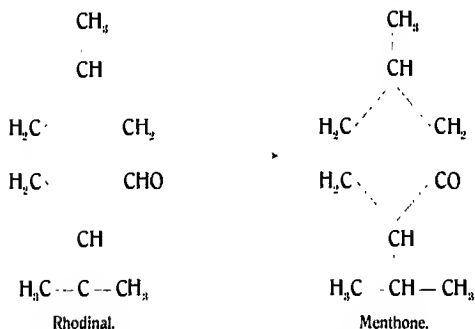
As with citronellol, so with citronellal, there is a difference of opinion concerning the identity of the products from different sources. Whereas *e. g.* Tiemann and Schmidt, also Schimmel & Co.,

¹⁾ Tiemann, Berl. Berichte 31 (1898), 3305.

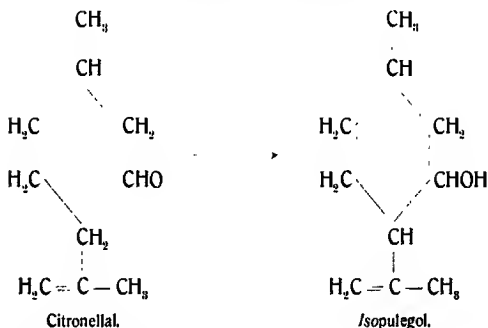
²⁾ Tiemann, Berl. Berichte 32 (1899), 815.

³⁾ *Ibidem* 834.

regarded them as identical, Barbier and Bouveault¹⁾ claimed them to be isomeric. They state that citronellal from citronella oil has a different constitution (the first formula, p. 414) from that obtained upon the oxidation of citronellol from rose oil (the second formula, p. 414). To the latter they apply the name "rhodinal". They base their claims on the rearrangement of rhodinal to menthone,



whereas citronellal rearranges itself to isopulegol.



The change of rhodinal to menthone is regarded as non-proven by Tiemann and Schmidt.²⁾ According to the examinations of

¹⁾ Compt. rend. 122 (1896), 737; Bouveault and Gourmand, *ibidem* 138 (1904), 1699; Bouveault, Bull. Soc. chim. III, 23 (1900), 458.

²⁾ Berl. Berichte 30 (1897), 38.

these investigators, the rhodinal semicarbazone described by Barbier and Bouveault is a mixture of racemic citronellal semicarbazone and little isopulegone semicarbazone, whereas their supposed menthone semicarbazone is racemic isopulegone semicarbazone. When hydrolyzed with hydrochloric acid, isopulegone is regenerated which has an odor resembling that of menthone. It is on this that the erroneous assumption of the French scientists is said to be based.

The observations made by Harries and Himmelmann,¹⁾ while studying the action of ozone on citronellal, seem to indicate that the latter is not a chemical unit but a mixture of two isomeric aldehydes to which the two formulas, given at the beginning of this chapter, may be assigned. In the commercial products from different sources, the ratio of these two isomers varies. This assumption would seem to throw light on much that was previously little understood.

When carefully oxidized with silver oxide, citronellal yields the corresponding oily citronellic acid,²⁾ $C_{10}H_{14}O_2$. Energetic oxidation yields the same products obtained from citronellol, viz., acetone and β -methyladipic acid.³⁾ With hydroxylamine, citronellal yields a liquid oxime which when dehydrated, yields the nitrile of citronellic acid.⁴⁾ The phenylhydrazone is likewise oily. So far as present observations go, the semicarbazone obtained with semicarbazide is a chemical unit and hence is well suited for the identification of citronellal. It is obtained quantitatively when an alcoholic solution of the aldehyde is shaken with a solution of semicarbazide hydrochloride and sodium acetate. When recrystallized from chloroform or ligroin it is obtained in white laminae which melt at 82.5° .⁵⁾ The racemic modification melts at 96° , the thiosemicarbazone at 54 to 55° .

Like citral, so citronellal yields with pyrotartaric acid and β -naphthylamine a naphthocinchoninic acid,⁶⁾ which can be utilized

¹⁾ Berl. Berichte 41 (1908), 2187.

²⁾ Semmler, Berl. Berichte 24 (1891), 208; 26 (1893), 2256.

³⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 908.

⁴⁾ Semmler, Berl. Berichte 26 (1893), 2255.

⁵⁾ Tiemann and Schmidt, Berl. Berichte 30 (1897), 34; Tiemann, *ibidem* 31 (1898), 3307.

⁶⁾ Doebner, Berl. Berichte 27 (1894), 2025.

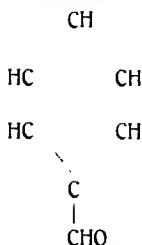
for purposes of identification. It is prepared like the corresponding citral derivative. The crude *α*-citronellyl-*β*-naphthocinchoninic acid is recrystallized from alcohol containing hydrogen chloride. The hydrochloride is dissolved in ammonia and the ammonium salt decomposed by acetic acid. The compound thus purified crystallizes from dilute alcohol in colorless needles that melt at 225°. When heated beyond its melting point, the acid splits off carbon dioxide and is converted into citronellyl-*β*-naphthoquinoline, a base that crystallizes from dilute alcohol or ligroin in the form of needles with a silky lustre and melts at 53°.

More rapid, however, than the identification by means of the naphthocinchoninic acid, is that by means of the semicarbazone (see above).

Upon condensation with acetone, citronellal yields citronellylidene acetone which yields a semicarbazide-semicarbazone that melts at 167°.¹⁾ Citronellylidene cyanacetic acid,²⁾ prepared like the corresponding citral compound, melts at 137 to 138° and yields a characteristic, difficultly soluble sodium salt that can be utilized for the separation of citral.

CYCLIC (AROMATIC) ALDEHYDES.

Benzaldehyde.



Benzaldehyde occurs rather frequently in volatile oils. Its existence in these oils is due to the presence, in parts of plants,

¹⁾ Rupe and Lotz, Berl. Berichte 36 (1903), 2796; Rupe and Schlochoff, *ibidem* 4377.

²⁾ Tiemann, Berl. Berichte 32 (1899), 824.

of certain glucosides which, upon hydrolysis, yield benzaldehyde, hydrocyanic acid, and glucose. Such glucosides are amygdalin, lauroccerasin, prulaurasin and sambunigrin.

Bitter almond oil consists almost entirely, wild cherry bark oil and cherry laurel oil in large part of benzaldehyde. Its presence has also been established in the oils of Ceylon cinnamon and cinnamon leaf, in indigofera oil, in the oils of Roman and French cassie blossoms, in neroli oil, niaouli oil, patchouli oil, &c. Almost invariably hydrocyanic acid is present with the benzaldehyde. (Compare under hydrocyanic acid where the names of all plants yielding benzaldehyde and hydrocyanic acid upon distillation are recorded.)

As first material for the artificial preparation of benzaldehyde, toluene, $C_6H_5CH_3$, from coal tar is used. This hydrocarbon is chlorinated to either benzylchloride, $C_6H_5CH_2Cl$, or benzalchloride, $C_6H_5CHCl_2$, and the chlorides are converted into benzaldehyde.

Benzaldehyde is a colorless liquid and has the characteristic odor of moistened comminuted almonds. Contrasted with bitter almond oil containing hydrocyanic acid, it is comparatively harmless.¹⁾ It is readily soluble in the ordinary solvents and is dissolved even by water in the ratio of about 1:200. It is reported to boil at 179° . The following constants have been observed in the laboratory of Schimmel & Co.:

B. p. 177.3 (733 mm.), $45'$ (5 mm.); $d_{15} 1.050$ to 1.055 ; $n_D^{20} \pm 0$; $n_{D20} 1.544$ to 1.546 ; soluble in 8 vols. of 50 p. c., 2.5 to 3 vols. of 60 p. c., and 1 to 1.5 vols. of 70 p. c. alcohol.

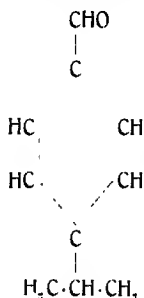
Of the numerous derivatives that have been prepared, particularly in condensation reactions, the following may serve for the identification of benzaldehyde: the acid sulphite addition product, the semicarbazone melting at 214° and the phenylhydrazone melting at 156° . Atmospheric oxygen readily oxidizes benzaldehyde to benzoic acid which frequently crystallizes out when bottles are not completely filled with the aldehyde. The addition of 10 p. c. alcohol retards this oxidation, the addition of a smaller amount accelerates it.²⁾

¹⁾ Report of Schimmel & Co. October 1893, 6.

²⁾ Report of Schimmel & Co. April 1895, 12.

Because of its method of preparation, artificial benzaldehyde almost invariably contains more or less chlorinated products, which impair its odor. Hence these render it unsuited for perfumery purposes and for the production of liqueurs. However, by means of careful purification, artificial benzaldehyde can be made absolutely free from chlorine. A good product should, therefore, be free from chlorine and the absence of halogen should be ascertained by proper tests. (Compare the chapter: "The examination of volatile oils".)

Cuminic aldehyde.



Cuminic aldehyde (*p*-isopropyl benzaldehyde, euminol) has been observed repeatedly in volatile oils. It is the principal constituent of oil of cumin and has also been found in the oils of holdo leaves, Ceylon cinnamon, myrrh, cassie blossoms, *Eucalyptus haemastoma*, *E. hemiphloia*, *E. odorata*, *E. oleosa*, *E. populi-fera*, and water hemlock.

Cuminic aldehyde purified through the acid sulphite addition product has the following properties:

Sp. gr. 235,5°; d_{15}^4 0,9818; α_D^{20} $\pm 0^\circ$; 1) b. p. 232° (760 mm.), 109,5° (13,5 mm.); 2) d_{15}^4 0,972. 3)

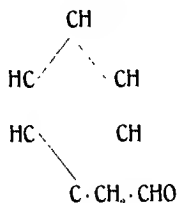
1) Journ. chem. Soc. 69 (1896), 1199.

2) Anschütz and Reitter, *Die Destillation unter verminderten Druck*, p. 73.

3) Kopp, Liebig's Annalen 114 (1855), 319

The semicarbazone of cuminic aldehyde melts at 210 to 211°, the phenyl hydrazone at 126 to 127°, the oxime at 58 to 59°. Upon oxidation it yields euminic acid which melts at 115°.

Phenylacetic aldehyde.



Although this aldehyde has not yet been found in a volatile oil, it may be mentioned here since it finds application in perfumery on account of its hyacinth-like odor. It can be prepared in one of several ways. Phenyl- α -chloro lactic acid, phenyl- α -bromo lactic acid or α -bromo styrene are commonly used as starting point.

Pure phenylacetic aldehyde is a colorless liquid of an exceedingly intensive hyacinth-like odor. In contact with the skin it colors the latter yellow. Radziszewski¹⁾ enumerates the following constants:

B. p. 205 to 207°; d 1,085.

Schimmel & Co. have determined the following constants:

B. p. abt. 75° (5 mm.); d_{15} 1,0315 to 1,0521; n_D^{20} 1,52536 to 1,53370; soluble in about 3 vols. of 70 p. c. alcohol.

Phenylacetic aldehyde oxidizes readily to phenylacetic acid. Oxidized with nitric acid it yields benzoic acid. It manifests a decided tendency to polymerize, hence it is difficult to preserve unchanged. It should be tested for halogen, the presence of which would indicate insufficient purification. (Compare the chapter "The examination of volatile oils", under benzaldehyde.)

¹⁾ Berl. Berichte 9 (1876), 372.

Cinnamic aldehyde.

CH

HC CH

HC CH

C·CH:CH·CHO

Cinnamic aldehyde occurs in Ceylon cinnamon oil, in cinnamon leaf oil, cinnamon root oil, Japanese cinnamon oil, oil of myrrh, oil of cassia and oil of patchouli.

Artificially it is obtained by the condensation of benzaldehyde with acetic aldehyde.

It is a yellow liquid possessing a characteristic cinnamon-like odor. Products made by Schimmel & Co. revealed the following properties.

B. p. under atmospheric pressure abt. 252° with partial decomposition, 128 to 130° (20 mm.), 118 to 120° (10 mm.); d_{15}^4 1.054 to 1.058; n_D^{20} 1.61949,¹⁾ its index of refraction, n_D^{20} 1.61949,¹⁾ is the highest observed in connection with volatile oils. When cooled, it congeals to a solid, light yellow mass that melts at -7.5°. It is soluble in about 25 vols. or more of 50 p. c. alcohol, also in about 7 vols. of 60 p. c. alcohol and in 2 to 3 vols. of 70 p. c. alcohol. In petroleum ether it is practically insoluble.

Cinnamic aldehyde reacts with both acid and neutral sulphite. When it is to be separated by means of the bisulphite addition product, an excess of the bisulphite solution should be avoided since a second molecule will combine with the formation of the water-soluble $C_6H_5 \cdot C_2H_3(SO_3Na) \cdot CH(OH) \cdot SO_3Na$. Other derivatives that are suited to the identification of cinnamic aldehyde are the semicarbazone, m. p. 208°, the phenylhydrazone, m. p. 168°. Furthermore cinnamic acid, which is formed even by the action of atmospheric oxygen, and its oxidation products benzaldehyde and benzoic acid.

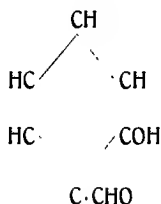
In connection with artificial cinnamic aldehyde care should be taken that it be free from chlorine, since the presence of

¹⁾ Brühl, Liebig's Annalen 235 (1886), 18, 31.

chlorine is an indication of insufficient purity. For the detection of chlorine, also for the quantitative determination of cinnamic aldehyde compare the chapter "The examination of volatile oils".

In addition to the aromatic aldehydes already mentioned, a number of others should be enumerated in which benzene hydrogen has been replaced by hydroxy or alkoxy groups. Although widely distributed in the vegetable kingdom, they occur in small amounts only. In as much as they possess valuable properties as perfumes, most of them are also prepared synthetically, hence there exists an extensive patent literature.

Salicylic aldehyde.



Salicylic aldehyde (*o*-hydroxybenzaldehyde) has been found in the oils of *Spiræa* (*S. Ulmaria*, *S. Filipendula*, *S. digitata*, *S. lobata*), in the leaves of *Honialium tomentosum*, in *Cordia asperima* (?), and in the oil of *Crepis lætida*.

Formerly it was obtained by the oxidation of saligenin prepared from willow bark. At present it is produced according to the well-known synthesis of Reimer and Tiedmann¹⁾ by the action of chloroform and aqueous alkali on phenol.

According to Perkin,²⁾ salicylic aldehyde boils at 197°. Its sp. gr. is $d_{16} = 1.1698$. In the ordinary solvents it is readily soluble, and but slightly in water. The latter solution is colored a deep violet by ferric chloride.

For the purpose of isolating salicylic aldehyde, its phenol nature (solubility in alkali) as well as its aldehyde character

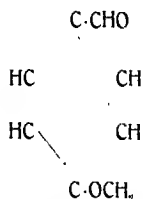
¹⁾ Berl. Berichte 9 (1876), 824.

²⁾ Journ. chem. Soc. 69 (1896), 1200.

(acid sulphite addition product) can be utilized. When reduced it yields saligenin, m. p. 86°, when oxidized salicylic acid, m. p. 155 to 156°. The oxime melts at 57°, the phenyl hydrazone at 96°.

Salicylic aldehyde is of special importance as the starting point in the manufacture of coumarin.

Anisic aldehyde.



Anisic aldehyde (*p*-methoxy benzaldehyde), also known as aubépine, results upon oxidation of anethol. Hence it is found in old, anethol-containing oils, such as anise oil, staranise oil and fennel oil. Its presence has likewise been demonstrated in the extract of Tahiti vanilla, and in Roman and French cassia blossom oils. The odor of the flowers of *Crataegus Oxyacantha*, *Pyrus communis*, *Sorbus Aucuparia*, *Viburnum Tinus*, and *Lirica arborea*, would seem to indicate¹⁾ that anisic aldehyde is contained in them, but as yet no chemical proof has been brought forward.

Artificially, anisic aldehyde is prepared by the oxidation of anethol by means of nitric acid or chromic acid mixture, or by methylation of *p*-hydroxy benzaldehyde. When purified by means of the acid sulphite addition product, anisic aldehyde is a colorless liquid which boils at 248° (corr.).²⁾ Its odor resembles that of the flowers of *Crataegus Oxyacantha*. The properties of anisic aldehyde, as prepared on a large scale, have been determined by Schimmel & Co.:

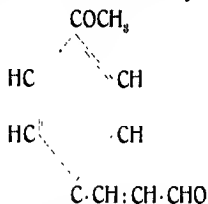
B. p. 91° (4 mm.); $d_{15} 1.126$ to 1.129 ; $n_D^{20} 1.572$ to 1.574 ; soluble in 7 to 8 vols. of 50 p. c. alcohol. The aldehyde can be characterized by means of its oxidation to anisic acid

¹⁾ Report of Schimmel & Co. October 1903, 20; Verschaffelt, Chem. Weekblad 1903, No. 25, 1; Report of Schimmel & Co. October 1903, 161.

²⁾ Perkin, Journ. chem. Soc. 69 (1896), 1200.

(m. p. 184°) into which it passes over when improperly kept. Furthermore, by means of its semicarbazone (m. p. 203 to 204°), or of its oximes, of which one modification melts at 63°, the other at 132°.

p-Methoxycinnamic aldehyde.



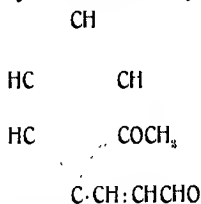
p-Methoxycinnamic aldehyde (*p*-cumaric aldehyde methyl ether) has been found in esdragon oil by Daufresne.¹⁾ Its constants are:

B. p. 170 (14 mm.); d_4^{20} , 1.137. The semicarbazone melts at 222°, the oxime at 154°.

The bisulphite addition product is not readily decomposed. When oxidized with potassium permanganate in acid solution, anisic acid results. Silver oxide oxidizes it to *p*-methoxycinnamic acid (m. p. 170°).

The aldehyde is identical with the artificial product prepared by Seholtz and Wiedemann.²⁾

o-Methoxycinnamic aldehyde.



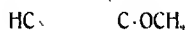
o-Methoxycinnamic aldehyde (*o*-cumaric aldehyde methyl ether) occurs occasionally as stearoptene in the oil of the Chinese

¹⁾ *Étude de l'essence d'estragon et de quelques dérivés de l'estragol*. Thèse, Paris 1909; Compt. rend. 145 (1907), 875; Bull. des Sciences pharmacologiques, January 1908, 11; Report of Schimmel & Co. April 1908, 49.

²⁾ Berl. Berichte 36 (1903), 853.

cinnamon cassia¹⁾ and separates in solid form from the last fractions of cassia oil. M. p. 45 to 46 ; b. p. abt. 295° with partial decomposition, 160 to 161 under 12 mm. pressure. It dyes the skin intensively yellow and is readily decomposable even away from air and light. Oxidation with permanganate converts it into methyl salicylic acid, m. p. 99 , which when boiled with hydriodic acid is converted into salicylic acid. With silver oxide it yields *l*-methylcumaric acid which melts at 182 to 183°. The oxime melts at 125 to 126 , the phenylhydrazone at 116 to 117°.

Vanillin.



Vanillin, the methyl ether of protocatechuic aldehyde, occurs widely distributed in the Vegetable Kingdom but mostly in very small amounts. Moreover, in the living plant it does not appear to occur as such, but is presumably the product of fermentation of a glucoside. It is the characteristic constituent of vanilla beans. It has also been found in the flowers of *Nigritella suaveolens*, in the oil of *Spiraea Ulmaria*, in Peru balsam, and in oil of cloves. It appears to be contained in the wood substance of numerous plants and can frequently be recognized by means of its characteristic agreeable odor, especially after proper preliminary treatment of the material to be tested. Of plants and plant materials in which its presence may be assumed, the following may be mentioned: Siam benzoës, Asa fetida, umbelliferous opopanax, the rosin of species of larch, maté, potato skins, fresh linden bark, cork, bulbs of dahlia, asparagus shoots, crude beet sugar, and the aqueous extract of the seed of *Lupinus albus*. Traces of vanillin can also be obtained from the sulphite wastes of the manufacture of cellulose, also from saw-dust by heating it under pressure with water to 180°.

¹⁾ Bertram and Kürsten, Journ. f. prakt. Chem. II. 51 (1895), 316.

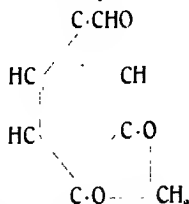
Artificially vanillin was first obtained from conifcrin, a glucoside found in the cambial juice of conifers.¹⁾ Other methods have been devised since then. At present it is obtained principally by the oxidation of *isocugenol*.

Vanillin constitutes colorless, prismatic needles which are readily soluble in the common organic solvents. It is also readily soluble in boiling water, but difficultly soluble in cold water. Both the aqueous and alcoholic solutions are colored blue by ferric chloride. Its melting point is usually recorded as 80 to 81°. Schimmel & Co., however, observed 82 to 84° in connection with pure preparations. When carefully heated it sublimes without decomposition. It boils at 285° (in a current of carbon dioxide), or at 170° under 15 mm. pressure.

Of crystalline derivatives the following may be mentioned: the methyl ether, m. p. 42 to 43°; the ethyl ether, m. p. 64 to 65°; the acetyl derivative, m. p. 77°; the benzoate, m. p. 75°; and the oxime, m. p. 121 to 122°. Upon oxidation it yields vanillic acid, m. p. 207°. Its isolation can be accomplished by means of alkali bisulphite, *p*-bromophenylhydrazine or *m*-nitrobenzylhydrazine. For the quantitative determination of vanillin compare the chapter "The examination of volatile oils".

In commerce vanillin is frequently found adulterated. The following list of substances has thus far been found as adulterants, *viz.*, *acetisocugenol*, *antifebrine*, *benzoic acid*, *coumarin*, *terpin hydrate*, and *sugar*. The melting point, its solubility in water, alcohol and ether, and its behavior toward acid sulphite are the principal criteria in testing vanillin for its purity.

Heliotropin.



Heliotropin, also known as *piperonal*, is the methylenic ether of *protocatechuic aldehyde*. It has been observed but once in a

¹⁾ Tiemann and Haarmann, Berl. Berichte 7 (1874), 613.

volatile oil and then only in minimal amount, namely in the oil from the flowers of *Spiraea Ulmaria*. The supposed occurrence in some varieties of vanilla bean assumed by Busse¹⁾ is still doubtful.²⁾ Furthermore, it is not known whether the heliotropin-like odor of certain flowers, such as the heliotrope, is due to the presence of this aldehyde or not.

As source for the artificial preparation of piperonal, piperin was formerly used. At present it is obtained much more cheaply by the oxidation of *isosafrol*.

Heliotropin constitutes colorless, lustrous crystals that have a heliotrope-like odor, that melt at 35 to 36° and that boil at 236°. It is readily soluble in alcohol, ether and similar solvents; difficultly soluble in cold water, more readily in boiling water. From hot water it can be obtained in crystals an inch long and more. In glycerin it is very sparingly soluble, somewhat more in paraffin oil, comparatively readily soluble in olive oil (about 6 p. c.). At a temperature of 10° it is soluble to the extent of about 5 p. c. in 70 percent. alcohol.

As aldehyde, heliotropin combines with acid sulphite. Upon reduction piperonyl alcohol, m. p. 51°, results; upon oxidation piperonylic acid, m. p. 227.5 to 228°. Other derivatives are its monobromide, m. p. 129°, its mononitro compound, m. p. 94.5°, the anilide, m. p. 65°, the thiosemicarbazone, m. p. 185°, and the semicarbazone, m. p. 224 to 225°.

It may be mentioned that heliotropin possesses antipyretic and antiseptic properties, and that it may be used as antidote in strychnine poisoning.

Heliotropin should be stored in a cool, dark place since it turns yellow or even brown and is decomposed when exposed to light.³⁾

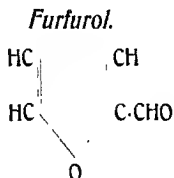
When examined for adulterants, the melting point and solubility should be determined. Its behavior toward acid sulphite with which it reacts readily may also be ascertained.

¹⁾ Arbeiten a. d. Kaiserl. Ges.-Amt 15 (1898 to 1899), 108.

²⁾ Walbaum, *Wallach-Festschrift*. Göttingen 1909. p. 649; Report of Schimmel & Co. October 1900, 142.

³⁾ Report of Schimmel & Co. April 1904, 128.

In this connection a heterocyclic aldehyde may be mentioned, namely,



Its presence in volatile oils is possibly due to the united action of heat and acid on the cell-membrane and other carbohydrates of the crude materials subjected to distillation in the presence of water.¹⁾

In as much as this aldehyde is relatively soluble in water (in 11 parts at 13°) it is contained mostly in the aqueous distillate or in the first fraction of the oil.

Furfural has been found in the following oils, viz., pine tar oil, oil of cade, the first fraction of orris oil, clove oil,²⁾ oil of Ceylon cinnamon, petitgrain oil, in the oil of *Apocynum androsaemilolium*, in the aqueous distillates from oils of cypress, savin, vetiver, orris, West Indian sandalwood, ambrette seeds, cloves, clove stems, caraway, and in the first distillate of bay and lavender oils. As a matter of interest, it may here be mentioned that E. Erdmann³⁾ observed furfural and furfural alcohol in the volatile oil of the roasted coffee beans.

The boiling point of the pure compound is 160.5° (742 mm.); its density d_4^{20} 1.1594. When oxidized it yields pyromucic acid, m. p. 132 to 133°. Of its derivatives the following may here be mentioned, viz., the phenyl hydrazone, m. p. 97 to 98°, the semicarbazone, m. p. 197°, and the semioxamazone, m. p. 264°. It can be identified most conveniently by means of the well-known color reaction with *p*-toluidine or aniline hydrochloride.

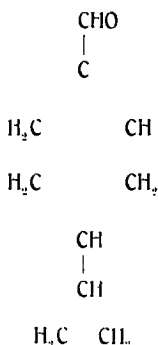
¹⁾ Report of Schimmel & Co. October 1899, 36.

²⁾ Oil of cloves also contains α -methyl- and a dimethyl furfural.

³⁾ Berl. Berichte 35 (1902), 1851.

ALICYCLIC (HYDROAROMATIC) ALDEHYDES.

So far as occurrence in volatile oils is concerned, this group of aldehydes is much less important than the others already considered.

Phellandral.

Phellandral, to which in all probability the above formula may be assigned, is found in small amounts in the oil of water-fennel. B. p. 89 (5 mm.); $d_{15} 0.9445$; $\alpha_D - 36' 30''$; $n_{D20} 1.4911$.¹⁾ When exposed to air, or when treated with silver oxide, phellandral is readily oxidized to the corresponding acid which melts at 144 to 145. Of its derivatives the oxime, m. p. 87 to 88, the semicarbazone, m. p. 202 to 204, and the phenylhydrazone, m. p. 122 to 123, may be mentioned.

Aldehyde C₁₀H₁₈O from lemongrass oil. B. p. 68 (6 mm.); $d_{15} 0.9081$; $\alpha_D + 0 50'$; $n_{D20} 1.45641$. M. p. of the semicarbazone 188 to 189.

Aldehyde C₁₀H₁₈O from gingergrass oil. B. p. 221 to 224" (754 mm.), 76 to 78 (5 mm.); $d_{15} 0.9351$; $\alpha_D \pm 0$; $n_{D20} 1.47348$. Upon reduction an alcohol C₁₀H₁₈O results, the phenylurethane of which melts at 100 to 101. When exposed

¹⁾ Report of Schimmel & Co. October 1904, 88.

to the air this aldehyde is oxidized to an acid $C_{10}H_{18}O_2$, m. p. 106 to 107°, which can also be obtained from the saponification liquid of gingergrass oil. Derivatives: oxime, m. p. 115 to 116°, semicarbazone, m. p. 169 to 170°, semioxamazone, m. p. 244 to 245°, phenylhydrazone, m. p. 63°, β -naphthocinchonic acid, m. p. 261°.

KETONES.

ALIPHATIC KETONES.

Of the aliphatic ketones only a few are found in volatile oils. They are mostly methyl ketones which can be isolated by means of their acid sulphite addition products. The lower members are water-soluble and hence are found either in the aqueous distillate or in the first portion of the oil which distills over.

Acetone, $CH_3 \cdot CO \cdot CH_3$. This ketone has been observed not infrequently during the distillation of volatile oils, more particularly of leaf oils. Presumably it is formed during the process of distillation, but the reaction by which it is produced is not known. It has been found in the Atlas cedar oil, coca leaf oil, clove oil and in the distillate of patchouli leaves. Together with hydrocyanic acid, it has been found in the distillate of numerous plants, thus in that of *Triglochin maritima*¹⁾, *Thalictrum aquilegifolium*, *Nandina domestica*, *Phaseolus lunatus*, *P. Mungo*, *Linum usitatissimum*, *L. perenne*, *Hevea brasiliensis*, *H. Spruceana*, *Jatropha angustidens*, *Manihot bankensis*, *M. Glaziovii*, *M. palmata*, *M. utilissima*, *Passiflora alata*, *P. caerulea*, *P. edulis*, *P. laetida*, *P. hybrida*, *P. laurifolia*, *P. maculata*, *P. princeps*, *P. quadrangularis*, *P. suberosa*, *Tacsonia spec.* and *T. van Volxemii*.²⁾

Acetone boils at 56.5° and has the density d_{14} 0.79945. As characteristic derivatives the *p*-bromophenylhydrazone, m. p. 94°, and the oxime, m. p. 59 to 60°, may be mentioned. With iodine-potassium iodide solution a precipitate of iodoform results.

¹⁾ Greshoff, Pharm. Weekblad 45 (1908), 1165; Chem. Zentralbl. 1908, II, 1446.

²⁾ Greshoff, Arch. der Pharm. 244 (1906), 665.

Methyl-n-amyl ketone, $\text{CH}_3 \cdot \text{CO} \cdot (\text{CH}_2)_4 \cdot \text{CH}_3$, is contained in the low boiling portions of clove oil and is of importance so far as the characteristic odor of this oil is concerned. Its presence in Ceylon cinnamon oil has also been demonstrated. B. p. 151 to 152°; $d_{20} 0,8366$. The semicarbazone melts at 122 to 123°.

Ethyl-n-amyl ketone, $\text{CH}_3 \cdot \text{CH}_2 \cdot \text{CO} \cdot (\text{CH}_2)_4 \cdot \text{CH}_3$, occurs in the first fraction of French lavender oil. B. p. 169,5 to 170°; $d_{15} 0,8254$; $n_{D,20} 1,41536$; m. p. of semicarbazone 117 to 117,5°. It does not react with acid sulphite. Its oxidation with chromic acid yields *n*-capronic acid.¹⁾

Methyl-n-heptyl ketone, $\text{CH}_3 \cdot \text{CO} \cdot (\text{CH}_2)_6 \cdot \text{CH}_3$, frequently constitutes the bulk of Algerian oil of rue. In small amounts it is also found in French and Spanish oils of rue and in oil of cloves. It is a colorless oil with an agreeable odor resembling that of rue.

For methyl heptyl ketone isolated from oil of rue, the following constants have been ascertained:

M. p. 17°; cong. p. — 19°; b. p. 85 to 90° (7 mm.), 95,8 to 102° (24 mm.); $d_{20} 0,83178$.²⁾

Cong. p. — 15°; b. p. 193 to 194° (740 mm.); $d_{20} 0,821$.³⁾

B. p. 194,5 to 195,5° (763 mm.); $d_{15} 0,8296$.⁴⁾

B. p. 194 to 196°; 80 to 82° (15 mm.).⁵⁾

It reacts but slowly with acid sulphite solution. M. p. of the semicarbazone 118 to 119° or 119 to 120°. Oxidized with hypobromite it yields *n*-caprylic acid.

Methyl-n-nonyl ketone, $\text{CH}_3 \cdot \text{CO} \cdot (\text{CH}_2)_8 \cdot \text{CH}_3$, has long been known as the principal constituent of the common oil of rue from France and Spain. In Algerian oil of rue it usually plays but a subordinate role as compared with methyl heptyl ketone. For its preparation the French oil is commonly used, the ketone being isolated either by freezing it out, or by means of the acid sulphite addition product.

¹⁾ Report of Schimmel & Co. April 1903, 47; October 1903, 44.

²⁾ Thoms, Berichte d. deutsch. pharm. Ges. 11 (1901), 16.

³⁾ v. Soden and Henle, Pharm. Ztg. 46 (1901), 277.

⁴⁾ Power and Lees, Journ. chem. Soc. 51 (1902), 1568.

⁵⁾ Houben, Berl. Berichte 35 (1902), 3588.

Methylnonyl ketone is a colorless liquid at room temperature and possesses an odor similar to that of methylheptyl ketone. Its constants, as determined by different investigators, are as follows:

B. p. 226° (766 mm.), 230.65° (corr.), 122 to 123° (24 mm., corr.).¹⁾

M. p. -13.5°; cong. p. +12; b. p. 223 to 224° (774 mm.), 99° (7 mm.); d_{20}^{20} 0.82623.²⁾

B. p. 230 to 231° (740 mm.).³⁾

B. p. 229 to 233° (759 mm.), after regeneration from the semicarbazone 231.5 to 232.5° (761 mm.); d_{16}^{20} 0.8263.⁴⁾

Cong. p. +13°; b. p. 228 to 230°, 120° (20 mm.), 118° (18 mm.); d_{15}^{20} 0.8295; d_{20}^{20} 0.8263.⁴⁾

In connection with a synthetically prepared product Gorup-Besanez and Grimm⁵⁾ observed the following constants:

M. p. +15 to 16; b. p. 224°; $d_{17.5}^{20}$ 0.8295.

The oxime melts at 46 to 47°, the semicarbazone at 123 to 124°. Hypobronite oxidizes it to capric acid.

Diacetyl, $\text{CH}_3 \cdot \text{CO} \cdot \text{CO} \cdot \text{CH}_3$. Like furfural, this aliphatic diketone, which has been observed rather frequently in volatile oils, presumably owes its origin to the decomposition of certain plant constituents during the process of distillation. Inasmuch as it is rather water-soluble, it also is apt to concentrate in the cohobated aqueous distillate or in the first fractions. At times it even reveals its presence by means of its yellowish-green color and its quinone-like odor. In most instances, diacetyl is found together with methyl alcohol and furfural. It has been observed in the first distillate of a pine tar oil from Finland, in the cohobated aqueous distillate from the oils of cypress, savin, vetiver, orris, West Indian sandalwood, bay, and caraway.

B. p. 87.5 to 88°; density 0.9734 at 22°. Characteristic are its monophenylhydrazone, m. p. 133 to 134°; the oxime of the latter, viz. the diacetylhydrazoxime, m. p. 158°, and the osazone, m. p. 243°.

¹⁾ Carette, *Journ. de Pharm. et Chim.* II. 10 (1899), 256.

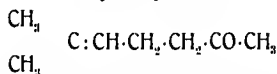
²⁾ Thoms, *loc. cit.* 8.

³⁾ v. Soden and Henle, *loc. cit.*

⁴⁾ Power and Lees, *loc. cit.*

⁵⁾ Houben, *loc. cit.* 3590.

⁶⁾ Liebig's *Annalen* 157 (1871), 279.

Methyl heptenone.

Of greater interest than the saturated ketones already enumerated, is the unsaturated methyl heptenone, $\text{C}_8\text{H}_{14}\text{O}$. It occurs as constituent of several volatile oils and has been obtained as decomposition product of related compounds. As companion to the closely related linalol, geraniol and citral, it occurs in Mexican linaloe oil, citronella oil and lemongrass oil. It also occurs in lemon oil, palmarosa oil and in the oil of *Barosma pulchella*. Apparently it owes its existence to the decomposition of the above-mentioned compounds. This decomposition can likewise be brought about artificially by oxidation. From the fractions boiling between 160 and 180° it can readily be isolated by means of its acid sulphite addition product.

As "Abban" product it was first obtained in the dry distillation of cineolic acid anhydride.¹⁾ It was then observed during the saponification of geranic acid nitrile,²⁾ and as oxidation product of citral.³⁾ It also results from the latter when treated with alkalis.⁴⁾ Synthetically it has been obtained from amylene bromide and acetyl acetone,⁵⁾ also by the interaction of the iodide of acetopropylalcohol, acetone and zinc dust.⁶⁾

It is a colorless, mobile liquid, with a penetrating odor reminding of amyl acetate, and is optically active. The physical constants as recorded do not agree any too well. For the ketone obtained from cineolic anhydride, Wallach records the following:

B. p. 173 to 174°; $d_{20} 0.8530$; $n_{D,20} 1.44003$.⁷⁾

For natural methyl heptenone Tiemann and Krieger determined:

B. p. 170 to 171° (760 mm.); $d_{20} 0.8499$; $n_D 1.4380$.⁸⁾

¹⁾ Wallach, Liebig's Annalen 258 (1890), 323.

²⁾ Tiemann and Semmler, Berl. Berichte 26 (1893), 2721.

³⁾ *Ibidem* 2719.

⁴⁾ Verley, Bull. Soc. chim. III. 17 (1897), 175.

⁵⁾ Barbier and Bouveault, Compt. rend. 122 (1896), 1422.

⁶⁾ Verley, Bull. Soc. chim. III. 17 (1897), 191.

⁷⁾ Liebig's Annalen 258 (1890), 325.

⁸⁾ Berl. Berichte 28 (1895), 2123.

For the "Abbau" product of citral Verley records:

B. p. 168° , 84° (56 mm.); $d_{15} = 0.910$ (1); $n_{D15} = 1.437$.¹⁾

For the methyl heptenone isolated from lemongrass oil and regenerated from the acid sulphite addition product, Schimmel & Co. observed:

B. p. 173° (758 mm.); $d_{15} = 0.855$; $n_{D20} = 1.43805$.²⁾

and for a product obtained by boiling citral with potassium carbonate solution:

B. p. 173 to 174° ; $d_{15} = 0.8656$.

When reduced in alcoholic solution with sodium, methyl heptenone is reduced to the secondary alcohol methyl heptenol, $C_8H_{16}O$.³⁾ This alcohol is likewise found among the decomposition products of geraniol and the saponification products of geranic acid nitrile. Methyl heptenone combines with acid sulphites to crystalline addition products, with hydroxylamine and phenylhydrazine to liquid condensation products, and with semicarbazide to a crystalline semicarbazone which can be utilized for the identification of the ketone. When oxidized, methyl heptenone breaks down into acetone and laevulinic acid, $C_6H_8O_4$.⁴⁾ In accordance with the above formula. Dehydrating agents, such as zinc chloride, convert it into dihydro-*m*-xylene, C_8H_{12} .⁵⁾

Methyl heptenone is readily recognized by its characteristic odor reminding of amylacetate. For its identification it is converted into the semicarbazone. As in the case of citral, this appears to be a mixture of isomers. However, a product with a constant melting point is obtained when prepared according to the directions of Tiemann and Krüger.⁶⁾ According to these investigators, a solution of 12 g. of semicarbazide hydrochloride and 15 g. sodium acetate in 20 cc. of water is added to a mixture of 12 g. methyl heptenone and 20 cc. of glacial acetic acid, and the mixed solutions set aside for half an hour. Upon the addition of water the semicarbazone separates as oil which soon

¹⁾ Verley, *loc. cit.* 176.

²⁾ Report of Schimmel & Co. April 1899, 65.

³⁾ Wallach, Liebig's Annalen 275 (1893), 171.

⁴⁾ Tiemann and Semmler, Berl. Berichte 28 (1895), 2128.

⁵⁾ Wallach, Liebig's Annalen 258 (1890), 326.

⁶⁾ Berl. Berichte 28 (1895), 2124.

congeals to a crystals which, when recrystallized from dilute alcohol, melt at 136 to 138°.

A compound well suited for identification is obtained when methyl heptenone is treated with bromine in the presence of soda lye.¹⁾ Hypobromous acid is added and bromine simultaneously substituted with the formation of the well crystallized derivative $C_8H_{12}Br_2O \cdot OH$. For its preparation 3 g of ketone are shaken with a solution of 3 g of sodium hydroxide and 12 g of bromine in 100 to 120 cc. of water. The reaction product separates as a heavy oil which soon congeals. It is taken up with ether, the ethereal solution shaken out with dilute soda solution. The residue left upon the evaporation of the ether is recrystallized from ligroin to which some animal charcoal has been added. The melting point of the pure, white crystals lies between 98 and 99°. Upon keeping they gradually decompose.

A method for the identification of methyl heptenone in the presence of citronellal and citral has been worked out by Tiemann.²⁾ It is based on the fact that methyl heptenone does not react with either a dilute or a concentrated solution of sodium sulphite and sodium acid carbonate, whereas the two aldehydes can be successively removed by shaking the oily mixture with the respective solutions of these salts.

AROMATIC KETONES.

As constituents of volatile oils, these ketones play but a minor role. The following may here be mentioned.

o-Hydroxyacetophenone, $CH_3 \cdot CO \cdot C_6H_4 \cdot OH$, and possibly its methyl ether, are contained in the oil of *Chione glabra*. B. p. 160 to 165° (34 mm.). With ferric chloride it produces a deep red color, with bromine water a yellow crystalline precipitate. The oxime melts at 112°, the phenylhydrazone at 108°. When fused with potassa, salicylic acid (m. p. 155°) results.

Anise ketone (*p*-methoxyphenylacetone), $CH_3 \cdot CO \cdot CH_2 \cdot C_6H_4 \cdot OCH_3$, possibly occurs in Russian anise oil and in bitter fennel oil. B. p. 263°; d_4^{20} 1.095. The oxime melts at 72°.

¹⁾ Tiemann and Semmler, Berl. Berichte 26 (1893), 2723.

²⁾ Berl. Berichte 32 (1899), 823.

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When reduced in alcoholic solution with sodium, methyl heptenone is reduced to the secondary alcohol methyl heptenol, $C_8H_{16}O$.³⁾ This alcohol is likewise found among the decomposition products of geraniol and the saponification products of geranic acid nitrile. Methyl heptenone combines with acid sulphites to crystalline addition products, with hydroxylamine and phenylhydrazine to liquid condensation products, and with semicarbazide to a crystalline semicarbazone which can be utilized for the identification of the ketone. When oxidized, methyl heptenone breaks down into acetone and laevulinic acid, $C_6H_8O_4$.⁴⁾ In accordance with the above formula. Dehydrating agents, such as zinc chloride, convert it into dihydro-*m*-xylene, C_8H_{12} .⁵⁾

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⁵⁾ Wallach, Liebig's Annalen 258 (1890), 326.

⁶⁾ Berl. Berichte 28 (1895), 2124.

pleted, those oily compounds that have not united with the sulphite are shaken out repeatedly with ether and removed. The carvone is then set free with soda lye and distilled with steam. This method may also be utilized for the quantitative determination of carvone. (See the chapter in "The examination of volatile oils".)

Artificially, carvone and its derivatives have been obtained in a variety of ways. However, a detailed account of the relationship between carvone, pinene, limonene, pinol, and terpineol would lead too far.

Carvone is a colorless liquid possessing a decided odor of caraway. At a low temperature it congeals.¹⁾ In the laboratory of Schimmel & Co. the following properties have been determined:

For *d*-carvone prepared from caraway oil by means of the sulphite addition product:

b.p. 230 (755 mm.), 91 (5 to 6 mm.); $d_{15} 0.9645$; $n_D^{20} 1.49952$;

For *l*-carvone prepared from spearmint oil by means of the sulphite addition product:

b.p. 230 to 231 (763 mm.); $d_{15} 0.9652$; $n_D^{20} 1.4988$; soluble in 17 vols. of 50 p. c. alcohol and in 4 vols. of 60 p. c. alcohol.

Commercial preparations, own manufacture, varied as follows:

$d_{15} 0.963$ to 0.966 ; $n_D^{20} +57^{\circ}30'$ to $+60^{\circ}$; $n_D^{20} 1.497$ to 1.500 ; soluble in 16 to 20 vols. of 50 p. c. alcohol, in 4 vols. of 60 p. c. alcohol, and in 1.5 to 2 vols. of 70 p. c. alcohol.

Carvone is an unsaturated ketone which combines with hydrogen chloride to form a liquid compound,²⁾ and with hydrogen bromide to one melting at 32° .³⁾ If hydrogen bromide be split off from the latter, an isomeric ketone $C_{10}H_{14}O$, eucarvone results.⁴⁾ The bromine substitution products obtained by the action of bromine on hydrobromcarvone, viz., the tribromide,

¹⁾ Wallach, Liebig's Annalen 252 (1889), 129, footnote.

²⁾ Goldschmidt and Kisser, Berl. Berichte 20 (1887), 487, 2071.

³⁾ *Ibidem* 2071; Baeyer, Berl. Berichte 27 (1894), 811.

⁴⁾ Baeyer, Berl. Berichte 27 (1894), 811; Wallach, Liebig's Annalen 305 (1899), 234; 339 (1905), 94.

For the "Abbau" product of citral Verley records:

B. p. 168° , 84° (56 mm.); $d_{11} 0.910$ (!); $n_{D13} 1.437$.¹⁾

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b.p. 230 to 231 (763 mm.); $d_{15} 0.9652$; $n_D^{20} 1.4988$; soluble in 17 vols. of 50 p. c. alcohol and in 4 vols. of 60 p. c. alcohol.

Commercial preparations, own manufacture, varied as follows:

$d_{15} 0.963$ to 0.966 ; $n_D^{20} +57^{\circ}30'$ to $+60^{\circ}$; $n_D^{20} 1.497$ to 1.500 ; soluble in 16 to 20 vols. of 50 p. c. alcohol, in 4 vols. of 60 p. c. alcohol, and in 1.5 to 2 vols. of 70 p. c. alcohol.

Carvone is an unsaturated ketone which combines with hydrogen chloride to form a liquid compound,²⁾ and with hydrogen bromide to one melting at 32° .³⁾ If hydrogen bromide be split off from the latter, an isomeric ketone $C_{10}H_{14}O$, eucarvone results.⁴⁾ The bromine substitution products obtained by the action of bromine on hydrobromcarvone, viz., the tribromide,

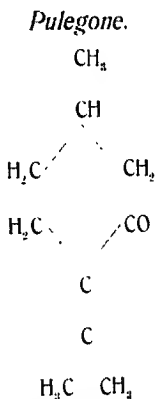
¹⁾ Wallach, Liebig's Annalen 252 (1889), 129, footnote.

²⁾ Goldschmidt and Kisser, Berl. Berichte 20 (1887), 487, 2071.

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⁴⁾ Baeyer, Berl. Berichte 27 (1894), 811; Wallach, Liebig's Annalen 305 (1899), 234; 339 (1905), 94.

Carvone is characterized by its peculiar odor by means of which it can readily be recognized. If it is to be isolated from a volatile oil, its hydrogen sulphide addition product or the sodium acid sulphite addition product may be utilized for this purpose. (See above.) It should be noted, however, that the hydrogen sulphide addition product does not melt at 187°, as stated by Baeyer,¹⁾ but at 210 to 211°. ²⁾



Pulegone, a ketone $\text{C}_{10}\text{H}_{16}\text{O}$, has thus far been found in labiate oils only. In these it frequently occurs in large amounts, occasionally together with menthol and menthone. European pennyroyal oil contains about 80 p. c. of this ketone. Diptam organum oil likewise consists largely of pulegone. Its presence in the following oils has also been determined, viz., in the oils of *Hedeoma pulegioides*, *Pycnanthemum lanceolatum*, *Bystropogon organifolius* and *Calamintha Nepeta*. In all of these oils it occurs in the dextrogyrate form. Its presence has further been ascertained in Canadian mint oil, in Japanese peppermint oil, and in marjoran oil. In these cases, however, references to the rotation are wanting.

¹⁾ Arch. der Pharm. 221 (1883), 285.

²⁾ Claus and Fahrion, Journ. f. prakt. Chem. II. 39 (1889), 365; Report of Schimmel & Co. April 1898, 47, footnote.

In as much as European pennyroyal oil consists chiefly of this ketone, pulegone can be obtained relatively pure by fractional distillation of this oil. In a purer state it can be separated from its compound with sodium acid sulphite or with neutral sodium sulphite. To cause the pulegone to combine with acid sulphite, the oil diluted with 1.4 its volume of alcohol is subjected to prolonged shaking with the aqueous sulphite solution.¹⁾ Its capacity to react with normal sulphite, also makes possible the quantitative estimation of pulegone. (See the chapter "The examination of volatile oils" under determination of ketones.) Furthermore, the semicarbazone, which can be hydrolyzed with acids, can be used for the purification of pulegone.

In a round-about way, pulegone has been obtained synthetically from citronellal.²⁾ Another ketone, which is not identical with natural pulegone, Wallach³⁾ obtained by condensation of 1,3-methylcyclohexanone with acetone.

Pulegone is a colorless liquid which turns slightly yellow upon prolonged standing. It possesses a peppermint-like, sweetish odor reminding of menthone.

For pulegone purified only by means of distillation, Beckmann and Pleissner⁴⁾ found the following constants:

B. p. 130 to 131° (60 mm.); d_{20} 0.9323; $[\alpha]_D^{20}$ -22.89; n_D^{20} 1.47018.

Barbier⁵⁾ records the following:

B. p. 222 to 223°; d_{20} 0.9293; $[\alpha]_D^{20}$ +25°15'.

For pulegone regenerated from the bisulphite addition product, Baeyer and Henrich⁶⁾ observed the following constants:

B. p. 100 to 101° (15 mm.); $[\alpha]_D^{20}$ +22.94°;

and Wallach:⁷⁾

B. p. 221 to 222°; d 0.936; n_D 1.4846.

¹⁾ Baeyer, Berl. Berichte 28 (1895), 652.

²⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 913; 30 (1897), 22.

³⁾ Berl. Berichte 29 (1896), 1597, 2955; Liebig's Annalen 300 (1898), 267.

⁴⁾ Liebig's Annalen 262 (1891), 3, 4, 20.

⁵⁾ Compt. rend. 114 (1892), 126.

⁶⁾ Berl. Berichte 28 (1895), 653.

⁷⁾ *Ibidem* 1965.

In connection with technical products prepared in the laboratory of Schimmel & Co., the following constants were observed:

d_{16}^{20} 0,939 to 0,941; α_D^{20} + 20 to + 23°; n_D^{20} 1,484 to 1,488; soluble in 4,5 vol. of 60 p. c. alcohol and in 1,5 vol. of 70 p. c. alcohol.

For a pure pulgone regenerated from its sulphite compound the following constants were observed:

B. p. 224° (750 mm.); 93 to 94° (8 to 9 mm.); 85° (5 mm.); d_{16}^{20} 0,9405; α_D^{20} + 20° 48'; n_D^{20} 1,48796.

As an unsaturated compound pulgone combines with bromine but yields a liquid dibromide. When heated with sodium ethylate, this yields pulgenic acid, $C_{10}H_{16}O_2$, from which a long series of derivatives has been obtained and which has served as the starting-point for extensive investigations. With hydrogen chloride and hydrogen bromide, pulgone yields crystalline addition products.¹⁾

Pulgone reveals the character of a ketone. When carefully reduced in alcoholic solution with metallic sodium, pulgol,²⁾ $C_{10}H_{18}O$, the corresponding alcohol is presumably first formed. Further addition of hydrogen reduces it to the saturated *l*-menthol, $C_{10}H_{20}O$.³⁾

When pulgone is heated with anhydrous formic acid or with alkali or with water in an autoclave to 250° it is hydrolyzed yielding acetone and 1,3-methylcyclohexanone, $C_7H_{12}O$.⁴⁾

Pulgone reacts with hydroxylamine, but the oxime of the normal ketone is not yet known. What was formerly regarded as such, is *isopulgone* oxime, since Wallach⁵⁾ has shown that in the presence of alkali and hydroxylamine pulgone undergoes isomerization to (active) *isopulgone*. At the same time the pulgone undergoes partial hydrolysis as indicated above, so that the yield of oxime leaves much to be desired.

¹⁾ Beckmann and Pleissner, *Liebig's Annalen* 262 (1891), 21; Baeyer and Henrich, *Berl. Berichte* 25 (1895), 653.

²⁾ Tiemann and Schmidt, *Berl. Berichte* 29 (1896), 914.

³⁾ Beckmann and Pleissner, *loc. cit.* 30.

⁴⁾ Wallach, *Liebig's Annalen* 289 (1896), 338; 365 (1909), 243.

⁵⁾ *Liebig's Annalen* 365 (1909), 240.

Wallach¹⁾ obtained the best results by observing the following directions:

To a solution of 10 g. of pulegone in 30 ccm. of absolute alcohol a solution of 30 g. solid potassa in 20 ccm. of water are added and then as rapidly as possible a solution of 1 g. of hydroxylamine hydrochloride in 1 ccm. of water. Care should be taken that the temperature of the reaction mixture does not exceed 75°. Finally, the mixture is heated for 10 minutes to 85° on a water bath. When cooled, the mass is poured on ice and allowed to stand. The oxime, which usually separates in large flakes, is shaken out with ether, the ether recovered by distillation and the residue subjected to steam distillation. The oxime passes over with the steam and separates in the form of fine needles which can be collected on an asbestos filter and recrystallized from ether or ligroin, when they melt at 120 to 121°. By repeated recrystallization from methyl alcohol, Wallach succeeded in raising the melting point to 123 to 124°. The oxime is levogyrate, $[\alpha]_{D_{25}} = -25.833^\circ$. When hydrolyzed by heating with oxalic acid, the oxime yields *isopulegone*. With sulphuric acid, however, pulegone is regenerated, since the sulphuric acid isomerizes the *isopulegone* back to pulegone.

In addition to this oxime two addition reaction products of pulegone with hydroxylamine are known: first, a compound $C_{10}H_{16}O \cdot NH_2OH$ ²⁾ which results from the addition of hydroxylamine to the pulegone and which melts at 155 to 157°; and secondly, a dioxime or rather hydroxamino oxime, $C_{10}H_{16}NOH \cdot NH_2OH$, which melts at 118°.³⁾

The semicarbazone which results from the action of semicarbazide on pulegone melts at 167.5 to 168°.⁴⁾ It is difficultly soluble in ether.

According to Baeyer and Henrich,⁵⁾ the identification, however, can be brought about more readily by means of the

¹⁾ Liebig's Annalen 365 (1909), 244.

²⁾ Beckmann and Pleissner, Liebig's Annalen 262 (1891), 6; Wallach, *ibidem* 365 (1909), 246.

³⁾ Semmler, Berl. Berichte 34 (1905), 146.

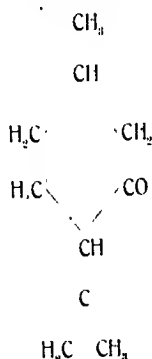
⁴⁾ Wallach, Liebig's Annalen 365 (1909), 246.

⁵⁾ Berl. Berichte 24 (1895), 654; comp. Baeyer and Prentice, Berl. Berichte, 29 (1896), 1078; Gage, Pharm. Review 16 (1898), 413.

characteristic bisnitrosopulegone. For its preparation a very small amount of hydrochloric acid is added to a solution of 2 ccm. of pulegone or pulegone-containing oil in 2 ccm. of ligroin and 1 ccm. of amyl nitrite which has been cooled down in a good freezing mixture. After a short time the bisnitroso compound separates in the form of fine needles which can be purified by drying them on porous plates and washing them with petroleum ether, when they melt at 81.5°. When recrystallized they decompose. Isopulegone does not give this reaction.

When oxidized with potassium permanganate, pulegone yields acetone and active methyladipic acid, $C_7H_{10}O_4$ melting at 84 to 85°. Because of these results, Schmitter¹⁾ has assigned to pulegone the above formula which also seems to explain the hydrolysis of this ketone into acetone and methyl hexanone.

Isopulegone.



This ketone, which has thus far not been found in volatile oils, may receive brief mention at least. As described on p. 446, it can be prepared by way of the oxime from pulegone. It can also be obtained by treating pulegone hydrobromide with basic lead nitrate.²⁾ Furthermore from citronellal, by converting this

¹⁾ Berl. Berichte 25 (1892), 3515.

²⁾ Harries and Roeder, Berl. Berichte 32 (1899), 3368.

into *isopulegol* (see p. 416) and the subsequent oxidation of this alcohol to *isopulegone*.¹⁾

Whereas the first two methods mentioned yield a single, active product, the change from citronellal to *isopulegone* results in a mixture of active and inactive ketone, the ratio of which varies according to the conditions of the experiment.²⁾ The active *isopulegone* yields a likewise active oxime which melts at 120 to 121° (respectively at 123 to 124°. See p. 446). The inactive ketone yields an inactive oxime which melts, according to Wallach, at 138 to 139°. According to Wallach, the separation of the two oximes is best accomplished by repeated recrystallization from methyl alcohol, in which the lower-melting oxime is more readily soluble. However, it is difficult to free the latter entirely from the higher-melting oxime, hence the poorly marked melting points.

The active *isopulegone* yields a semicarbazone which melts at 172 to 174° and which is readily soluble in ether, the inactive ketone a semicarbazone which melts at 182 to 183° and which is difficultly soluble in ether.

For an *isopulegone* obtained from *d*-citronellal, Tiemann and Schmidt³⁾ record the following constants:

B. p. 90° (12 mm.); $d_{15.5}^{20}$ 0.9213; n_D^{20} 1.4690.

For an *isopulegone* obtained from *pulegone* hydrobromide, Harries and Roeder⁴⁾ observed the following constants:

B. p. 98 to 100° (13 mm.); $d_{19.5}^{20}$ 0.9192; n_D^{20} 1.4687.

For its characterization the above-mentioned derivatives can be used.

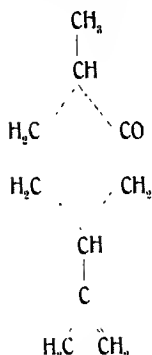
¹⁾ Tiemann and Schmidt, Berl. Berichte 30 (1897), 22; Tiemann, *ibidem* 32 (1899), 825.

²⁾ Wallach, Liebig's Annalen 365 (1909), 253. Harries and Roeder assumed the existence of two stereoisomeric ketones, viz., *u*- and *d*-*isopulegone*. Berl. Berichte 32 (1899), 3362. The former is identical with the active, the latter with the inactive *isopulegone*.

³⁾ Harries and Roeder as well as Semmler found 143°. Wallach (*loc. cit.*) explains this discrepancy by assuming that these investigators had an inactive oxime totally free from the active modification.

⁴⁾ Berl. Berichte 30 (1897), 28.

⁵⁾ *loc. cit.* 3371.

Dihydrocarvone.

It is only recently that this ketone has been found in caraway oil by the chemists of Schimmel & Co.¹⁾

Artificially it is obtained by the oxidation of dihydrocarveol with chromic acid in glacial acetic acid solution,²⁾ also by the reduction of carvone with zinc dust and alkali or glacial acetic acid.³⁾ In the latter case some dihydrocarveol always results.

Dihydrocarvone combines readily with sodium acid sulphite⁴⁾ and can be obtained in a pure state by means of this addition product.

It is a liquid, the odor of which resembles that of menthone as well as that of carvone. Wallach (*loc. cit.*) records the following properties:

B. p. 221 to 222°; $d_{20} 0.928$; $n_{D20} 1.47174$. The optical rotation varies according to the material from which it is prepared: *d*-carvone yields laevogyrate dihydrocarvone, *l*-carvone yields dextrogyrate dihydrocarvone.

Schimmel & Co. (*loc. cit.*) record the following constants for a dihydrocarvone isolated from caraway oil:

B. p. 221° (735.5 mm.); $d_{18} 0.9297$; $n_D - 16' 18''$; $n_{D20} 1.47107$.

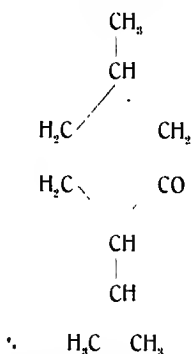
¹⁾ Report of Schimmel & Co. April 1905, 20.

²⁾ Wallach, Liebig's Annalen 275 (1893), 115.

³⁾ Wallach and Schrader, *ibidem* 279 (1894), 377.

The following characteristic derivatives may here be mentioned. According to Wallach¹⁾ the dibromide is readily obtained by the addition of bromine to a solution of dihydrocarvone in glacial acetic acid-hydrogen bromide. The active modifications of the dihydrobromide melt at 69 to 70°, the racemic mixture at 96 to 97°. The active oxime melts at 88 to 89°, the racemic mixture at 115 to 116°. The oximes deviate the plane of polarized light in the same direction as do the corresponding ketones.²⁾ The melting point of the semicarbazone is given by Wallach³⁾ as 189 to 191°. Harries and Roeder⁴⁾ record 201 to 202° for a preparation washed with ether. In addition to the constants, the above-mentioned derivatives may be utilized for the characterization of dihydrocarvone.

Menthone.



Both optical modifications of menthone, $\text{C}_{10}\text{H}_{18}\text{O}$, are found in nature. *d*-Menthone has been found in the oil of *Barosma pulchellum* and in American pennyroyal oil from *Hedeoma pulegioides*; *l*-menthone in Réunion geranium oil, buchu-leaf oil, peppermint oil and American pennyroyal oil. Menthone has also been found in European pennyroyal oil from *Mentha pulegium*,

¹⁾ Wallach and Schrader, Liebig's Annalen 279 (1894), 389; 286 (1895), 127.

²⁾ Wallach, Liebig's Annalen 275 (1893), 117; 279 (1894), 381.

³⁾ Berl. Berichte 28 (1895), 1960.

⁴⁾ *Ibidem* 82 (1899), 3372, footnote.

in the oil of *Dystropogon origanilolius* and in the oil from cassia blossoms (?), but the direction of rotation has not been recorded in these instances.

Inasmuch as menthone does not combine with acid sulphites, and since it cannot be obtained pure by fractional distillation, it must be isolated either by means of its oxime or by means of its semicarbazone which are prepared from the menthone fractions. It should be noted, however, that when these compounds are hydrolyzed, mostly with the aid of dilute sulphuric acid, the angle of rotation is altered.

Pure *l*-menthone with normal optical activity is readily obtained from menthol by oxidation with the chromic acid mixture recommended by Beckmann.¹⁾

Synthetically, menthone has been obtained by several methods.

Pure menthone is a mobile, colorless liquid with a peppermint-like odor and a slightly cooling, bitter taste. For the ketone obtained by the oxidation of menthol, Beckmann²⁾ found the following constants:

B. p. 207°; d_{20} 0,8960; $[\alpha]_{D^{20}}$ -28,18°; $n_{D^{120}}$ 1,4525;

and Binz³⁾ the following ones:

d_{20} 0,8934; $[\alpha]_{D^{20}}$ -27,67°.

According to Wallach,⁴⁾ menthone regenerated from its semicarbazone (m. p. 184°) possesses the following properties:

B. p. 208°; d 0,894; n_D 1,4496.

In the laboratory of Schimmel & Co. the following were observed:

d_{15} 0,894 to 0,899; α_D -20° 27' to -26° 10'; $n_{D^{20}}$ 1,450 to 1,451; soluble in 3 vols. of 70 p. c. alcohol.

d_{15} 0,8971; α_D -26° 10'; $[\alpha]_D$ -29,17°.

If *l*-menthone is treated at a low temperature with concentrated sulphuric acid it is changed to its dextrogyrate isomer.⁵⁾ In this

¹⁾ Beckmann, Liebig's Annalen 250 (1889), 325.

²⁾ *Ibidem* 327.

³⁾ Zeitschr. f. physik. Chem. 12 (1893), 727.

⁴⁾ Berl. Berichte 28 (1895), 1963.

⁵⁾ Beckmann, *loc. cit.* 334.

manner Beckmann obtained what he regarded as *d*-menthone of the same angle of rotation ($[\alpha]_D +28,1^\circ$) as the *l*-menthone ($[\alpha]_D -28,5^\circ$) from which he started. It was shown, however, that the former was not the optical antipode of the latter, but a mixture of *l*-menthone with the much more strongly active *d*-isomenthone. A highly dextrogyrate *d*-isomenthone he obtained in the following manner: Menthoxime was reduced, the resulting menthylamine treated with nitrous acid and the menthol thus obtained oxidized. This *isomenthone* had a specific angle of rotation of $+93,2^\circ$.¹⁾

Beckmann is of the opinion that the change in the angle of rotation brought about by acids is due to intermediary enolising. This interpretation is favored by the observation made by Mannich and Hâncu,²⁾ namely that *l*-menthone ($[\alpha]_D -22,4^\circ$) when subjected to prolonged heating with acetic acid anhydride to 240° yields the ester of 1-methyl-4-methoxyethyl cyclohexene-(2 or 3)-ol-3 (b. p. 98° at 11 mm.; $n_D +6,65^\circ$) which upon saponification yields a dextrogyrate menthone ($n_D +1,54^\circ$ in a 20 mm. tube).

In general, the change in the angle of rotation brought about by acids and alkalis is noteworthy.

When reduced in alcoholic solution with sodium, it is converted into the corresponding secondary alcohol, the *l*-menthol, $C_{10}H_{20}O$. As a by-product small amounts of the slightly dextrogyrate *isomenthol* result. When indifferent solvents are used some menthopinacone,³⁾ m. p. 94° , also is formed.

In dilute alcoholic solution, *l*-menthone condenses readily with hydroxylamine to *l*-menthoxime, m. p. 60 to 61° .⁴⁾ The other modifications of menthone yield oximes that are either liquid or possess a higher melting point.

If the oxime is treated with dehydrating agents, it is converted into an aliphatic nitrile, C_9H_7CN . When further modified this yields compounds that very much resemble the corresponding members of the citronellal group.⁵⁾ Upon molecular rearrange-

¹⁾ Berl. Berichte 42 (1909), 847.

²⁾ Berl. Berichte 41 (1908), 570.

³⁾ Beckmann, Journ. f. prakt. Chem. II 55 (1897), 18, 30.

⁴⁾ Beckmann, Liebig's Annalen 250 (1889), 330; Wallach, Liebig's Annalen 277 (1893), 157; 278 (1894), 304.

⁵⁾ Wallach, Liebig's Annalen 278 (1894), 308; 296 (1897), 120; 312 (1900), 171.

ment, induced by sulphuric acid, *l*-menthoneoxime yields a lactam, the menthone isoxime, m. p. 119°.¹⁾

Semicarbazide reacts on menthone with the formation of a semicarbazone that crystallizes in needles which melt at 184°.²⁾ Noteworthy is also the thiosemicarbazone, m. p. 155 to 157° and the semioxamazone, m. p. 177°.

If menthone is oxidized with a solution of chromic acid in glacial acetic acid, there results as first oxidation-product a keto acid $C_{10}H_{18}O_2$ (keto- or hydroxymethyllic acid).³⁾ Upon further oxidation with either potassium permanganate or chromic acid mixture, this is converted into the dibasic β -methyl adipic acid (β -pimelic acid of Arth),⁴⁾ hence into the same "Abbau" product obtained from pulegone and citronellal.

If isoamyl nitrite and hydrochloric acid are allowed to react on menthone in the cold, bisnitrosomenthone, $(C_{10}H_{17}O \cdot NO)_2$, m. p. 112.5° and the oxime of ketomenthylic acid, m. p. 103°, i. e. of the first oxidation product of menthone, are formed.⁵⁾

If bromine (2 mol.) is allowed to act on menthone (1 mol.) in chloroformic solution, there results a crystalline dibromementhone, $C_{10}H_{16}Br_2O$ (m. p. 79 to 80°). When acted upon by quinoline, this loses hydrogen bromide and is converted into thymol.⁶⁾

These changes, as also the conversion of menthone into 3-chloreymene brought about by Jünger and Klages,⁷⁾ are in harmony with the structural formula given above, which also expresses the relation of menthone to pulegone.

For the identification of menthone, the preparation of the semicarbazone or oxime is resorted to. For further characteri-

¹⁾ Beckmann and Mehrländer, Berl. Berichte 20 (1887), 1508; Wallach, Liebig's Annalen 278 (1894), 304.

²⁾ Wallach, Berl. Berichte 24 (1895), 1963; Beckmann, Liebig's Annalen 289 (1896), 366.

³⁾ Beckmann and Mehrländer, Liebig's Annalen 289 (1896), 368.

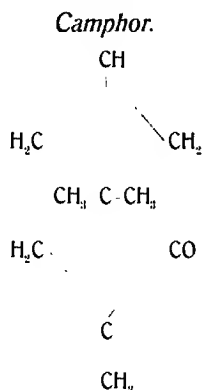
⁴⁾ Arth, Annal. de Chim. et Phys. VI. 7 (1886), 433; Beckmann and Mehrländer, loc. cit. 378; Manasse and Rupe, Berl. Berichte 27 (1894), 1818.

⁵⁾ Baeyer and Manasse, Berl. Berichte 27 (1894), 1913, 1914; see also Baeyer and Oehler, Berl. Berichte 29 (1896), 27.

⁶⁾ Beckmann and Eickelberg, Berl. Berichte 29 (1896), 418.

⁷⁾ Berl. Berichte 29 (1896), 315.

zation the ketone can be reduced to menthol and this converted into the benzoic ester (see menthol). For the quantitative determination of menthone consult the chapter on "The examination of volatile oils", ketone determinations.



d-Camphor, known also as Japanese or Laurus camphor in order to distinguish it from borneo camphor (*d*-borneol), is obtained on a large scale together with camphor oil by the distillation of the wood of *Cinnamomum Camphora* with water vapor. *d*-Camphor has also been found in Siam cardamom oil, American wormseed oil, camphor leaf oil, sassafras oil, apopin oil (?), rosemary oil, spike oil, in the oil of *Lavandula Stæchas*, Réunion basilicum oil, in the oil of *Basilicum canum*, and in Dalmatian sage oil; *l*-camphor in an oil of sage (*Salvia grandillora* [?]), *Artemisia Herba-alba*, *A. cana* (?), feverfew, tansy, and *Blumea balsamifera*; *i*-camphor in the oil of *Chrysanthemum sinense* var. *japonicum*. Camphor has also been reported as being present in a number of other oils, however, without record as to the angle or direction of rotation: in the oils of *Piper camphoriterum*, *P. angustilolium* var. *ossanum*, cinnamon root, and of Seychelles cinnamon bark. It may be added that an animal, the *Polyzonium rosalbum*, probably secretes camphor.¹⁾

¹⁾ Cook, Chem. Zentralb. 1901, I. 191.

Synthetically, camphor has been obtained by the dry distillation of the lead¹⁾ or calcium²⁾ salts of homocamphoric acid (Haller's hydroxycamphocarboxylic acid). However, this synthesis was only a partial one, since the homocamphoric acid was obtained from a derivative of camphor. The complete synthesis of camphor was later successfully accomplished by Komppa³⁾ who likewise succeeded in effecting the synthesis of camphoric acid.

Camphor can be isolated from the volatile oils containing it by freezing, if necessary after fractionation. It consists of a granular-crystalline, colorless, translucent mass with a decided tendency toward sublimation. It has a characteristic odor and is readily soluble in organic solvents. When cast on water, small pieces rotate in a very lively manner. By various observers its properties have been recorded as follows:

$d_{4,0}$ 0,9853 (determined for *l*-camphor);¹⁾
 in. p. 176,3 to 176,5°; b. p. 209,1° (759 mm., mercury completely within the vapor);²⁾
 m. p. 178,4°; $[\alpha]_D^{20}$ + 41,44° and — 42,76°;³⁾
 m. p. 175°; b. p. 204°;⁴⁾
 m. p. 175°; b. p. 204°; $[\alpha]_D^{20}$ + 44,22° in 20 p. c. alcoholic solution.⁵⁾

The world's consumption of camphor is very large, for the manufacture of celluloid ware alone enormous quantities are used. It is also used extensively in the manufacture of smokeless powder, for disinfection and for medicinal purposes. This great demand has given rise to its synthetic production from turpentine spirits on a commercial scale. In general, one of two methods is followed: Either pinene is converted into bornyl

¹⁾ Haller, *Contrib. à l'étude du camphre. Thèse. Nancy* 1879, p. 34; *Bull. Soc. chim.* III. 15 (1896), 324.

²⁾ Bredt and v. Rosenberg, *Liebigs Annalen* 249 (1896), 5.

³⁾ *Berl. Berichte* 36 (1903), 4332; 41 (1908), 4470; *Liebigs Annalen* 304 (1909), 110; 370 (1909), 209.

⁴⁾ Chautard, *Jahresber. d. Chem.* 1863, 555.

⁵⁾ Foerster, *Berl. Berichte* 23 (1890), 2983.

⁶⁾ Haller, *Compt. rend.* 105 (1887), 229.

⁷⁾ Landolt, *Liebigs Annalen* 189 (1877), 333.

⁸⁾ Beckmann, *Liebigs Annalen* 250 (1889), 353. - As to the influence exerted by the solvent and by the degree of concentration of the solution, compare Landolt, *loc. cit.*, also Rimbach, *Zeitschr. f. physik. Chem.* 9 (1892), 701.

chloride by means of hydrogen chloride, which by way of camphene and *isoborneol* is changed to camphor; or pinene is directly converted into esters of borneol or *isoborneol*.

At all times camphor has aroused the interest of chemists, hence the literature on this subject has grown to large dimensions. In conformity with the object of this book, only those derivatives will be considered that are suited to its identification.

Camphor is a ketone, $C_{10}H_{16}O$, but does not combine with acid sulphite. With hydroxylamine it yields an oxime (see below) from which, however, the ketone cannot be regenerated in a pure state for the reason that the oxime, when treated with acids, loses water and yields the amide and nitrile, $C_9H_{12}CN$, of campholenic acid.

If in ethylalcoholic solution, or better still in amylalcoholic solution, camphoroxime is reduced with sodium, two isomeric bornylamines result (m. p. 163° and 180° respectively).¹⁾ A similar base melting at 159 to 160° results when camphor is heated with ammonium formate to 220 to 230° .²⁾

Upon reduction with hydrogen camphor is converted into the alcohol borneol, $C_{10}H_{18}O$. If the addition of hydrogen takes place in indifferent solvents, some *isoborneol* results, also camphor pinakone, m. p. 157 to 158° .³⁾ In alcoholic solution it is reduced essentially to a mixture of borneol and *isoborneol*.⁴⁾

Oxidation with nitric acid yields dibasic camphoric acid, $C_{10}H_{16}O_4$ (m. p. of the active compound 187° , of the inactive modification 204 to 205°), and, if oxidized farther, tribasic camphoronic acid, $C_9H_{14}O_6$ (m. p. 139°). From the constitution of the decomposition products of these acids, numerous conclusions as to the constitution of camphor itself have been drawn. Of the many formulas proposed for this ketone, that of Bredt⁵⁾ given above is alone generally recognized at present.

Dehydrating agents act energetically on camphor. Thus the action of phosphoric acid anhydride yields *p*-cymene, of sulphuric

¹⁾ Forster, Journ. chem. Soc. 73 (1898), 386.

²⁾ Leuckart and Bach, Berl. Berichte 20 (1887), 104; Wallach and Griepenkert, Liebig's Annalen 269 (1892), 347.

³⁾ Beckmann, Berl. Berichte 27 (1894), 2348; Liebig's Annalen 292 (1896), 1.

⁴⁾ Beckmann, Journ. f. prakt. Chem. II. 55 (1897), 35.

⁵⁾ Berl. Berichte 26 (1893), 3049.

acid and zinc chloride yields other products as well. The action of iodine results in the formation of carvacrol.

For the identification of camphor it is converted into the oxime. This compound discovered by Naegeli¹⁾ is best prepared according to the method of Auwers.²⁾ To a solution of 10 p. camphor in 10 to 20 times its weight of 90 p. e. alcohol, a solution of 7 to 10 p. of hydroxylamine hydrochloride and 12 to 17 p. of soda lye are added. The mixture is digested on a boiling water bath until the substance precipitated by water dissolves to a clear solution in soda lye. The oxime precipitated by water is recrystallized from alcohol or ligroin. It melts at 118 to 119°.³⁾ The oxime from *d*-camphor is *laevogyrate*, that from *l*-camphor, *dextrogyrate*.⁴⁾ $[\alpha]_D$ in alcoholic solution $+41.3^\circ$.

For the identification of camphor the following compounds may also be utilized, *viz.* the semicarbazone, m. p. 236 to 238°, the *p*-bromophenylhydrazone, m. p. 101°, the oxymethylene derivative, m. p. 80 to 81°, and the benzylidene derivative, the active modification of which melts at 95 to 96° and the inactive modification at 78°.

Frequently it is necessary to identify camphor mixed with borneol. According to Haller's method,⁵⁾ the mixture is heated with succinic or phthalic acid anhydride and rendered alkaline causing the acid ester of borneol to go into solution. From this alkaline solution the camphor can be extracted with ether. According to another method, the borneol can be converted into esters with high boiling point, such as the succinate or stearate, and the camphor distilled over with water vapor. According to a third method, the camphor can be converted into its oxime and dissolved in dilute sulphuric acid. Shaking with ether then removes the borneol. However, the ethereal solution should in turn be shaken repeatedly with dilute sulphuric acid, since the ether also dissolves some of the camphor oxime.

¹⁾ Berl. Berichte 16 (1883), 497.

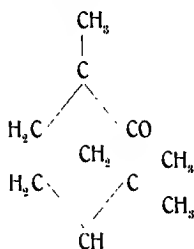
²⁾ *Ibidem* 22 (1889), 605.

³⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 10; Bredt and v. Rosenberg, Liebig's Annalen 250 (1896), 6.

⁴⁾ Beckmann, Liebig's Annalen 250 (1889), 354.

⁵⁾ Tiemann, Berl. Berichte 28 (1895), 2191.

⁶⁾ Compt. rend. 108 (1889), 1308.

Fenchone.

Fenchone is a ketone $C_{10}H_{16}O$ which closely resembles camphor but is liquid at ordinary temperature. In volatile oils both optically active modifications occur. *d*-Fenchone has been found in fennel oil and in the oil of *Lavandula Stoechas*, whereas *l*-fenchone has been found in the oil of *Arbor vitæ*. For the fenchone found in the oil of *Thuja plicata* the direction of rotation has not been recorded.

For its purification,¹⁾ the accompanying substances found in fraction 190 to 195° are removed by oxidation with either concentrated nitric acid or permanganate solution. Fenchone, being very stable toward oxidizing agents, is effected but little. Having thus been purified in a fair measure, it congeals in the cold and can be further purified by crystallization. However, small amounts of camphor, resulting from the oxidation of borneol esters, cannot be removed in this manner. Methods for the separation of these two ketones are given below. Artificially fenchone is obtained by the oxidation of fenchyl alcohol.

Pure fenchone is a water-white, somewhat oily liquid, with an intense, camphor-like odor and a bitter taste. As to its physical properties, Wallach²⁾ records the following data:

M. p. + 5 to 6°; $d_{15} 0.9465$, $d_{20} 0.943$; $[\alpha]_{D^{18}} +71.97^{\circ}$ and -66.94° resp. (in alcoholic solution);³⁾ $n_{D^{18}} 1.46306$.

¹⁾ Wallach, Liebig's Annalen 263 (1891), 130.

²⁾ Liebig's Annalen 263 (1891), 131; 272 (1893), 102.

³⁾ The lower angle of rotation is explained by a small camphor content of the oxime examined. Wallach, Liebig's Annalen 353 (1907), 215.

acid and zinc chloride yields other products as well. The action of iodine results in the formation of carvacrol.

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¹⁾ Berl. Berichte 16 (1883), 497.

²⁾ *Ibidem* 22 (1889), 605.

³⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 10; Bredt and v. Rosenberg, Liebig's Annalen 250 (1896), 6.

⁴⁾ Beckmann, Liebig's Annalen 250 (1889), 354.

⁵⁾ Tiemann, Berl. Berichte 28 (1895), 2191.

⁶⁾ Compt. rend. 108 (1889), 1308.

to 189°,¹⁾ also acetic and oxalic acids. Upon oxidation with concentrated nitric acid it also yields *isocamphoronic* acid and dimethyltricarballic acid.²⁾

In like manner as camphor yields *p*-cymene when treated with phosphoric acid anhydride, so fenchone yields *m*-cymene. When acted on by concentrated sulphuric acid, fenchone yields 4-acetyl-1,2-xylene.³⁾

By the action of sodium amide on fenchone, Semmler⁴⁾ obtained a dihydrofencholenic acid amide melting at 94°.

The semicarbazone of fenchone is formed exceedingly slowly. Only recently Wallach⁵⁾ has pointed out a convenient method for its preparation. 10 g. semicarbazide hydrochloride and 10 g. sodium acetate are dissolved in 20 ccm. of water. To this reagent a solution of 10 g. fenchone in 50 ccm. alcohol is added. The clear solution is set aside at room temperature for at least two weeks when the reaction product is distilled with steam. Alcohol and uncombined fenchone distil over, whereas the semicarbazone congeals in part to a compact mass, in part crystallizes from the hot water in which it is not completely insoluble. From dilute alcoholic solutions it crystallizes in thick, well-defined, shiny rhombic prisms, one centimeter long, which melt at 182 to 183°. The inactive form melts at 172 to 173° and does not possess the same crystallising capacity.

Inasmuch as the semicarbazone of camphor is formed much more readily, this difference in behavior can be utilized for the separation of camphor from fenchone.⁶⁾ Another method of separation, proposed by Semmler,⁷⁾ is based on the different behavior of the two ketones when boiled with sodium. Camphor reacts with the formation of sodium camphor, whereas fenchone is said to remain unchanged. Wallach's⁸⁾ investigations, however, have revealed that fenchone also does not remain unchanged

¹⁾ Wallach, *ibidem* 263 (1891), 134.

²⁾ Gardner and Cockburn, *Journ. chem. Soc.* 73 (1898), 708.

³⁾ Marsh, *Journ. chem. Soc.* 75 (1899), 1058; Wallach, *Liebig's Annalen* 315 (1901), 295.

⁴⁾ *Berl. Berichte* 39 (1906), 2578.

⁵⁾ *Liebig's Annalen* 353 (1907), 211.

⁶⁾ Wallach, *Liebig's Annalen* 353 (1907), 213 ff.

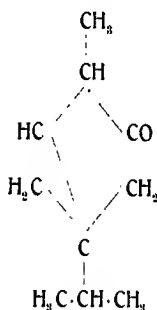
⁷⁾ *Berl. Berichte* 40 (1907), 4591.

⁸⁾ *Liebig's Annalen* 369 (1909), 65.

when boiled with sodium, but that ultimately the change is as complete as with camphor, the reaction only progresses more slowly. Hence the separation of fenelone from camphor by means of distillation over sodium is accompanied by considerable loss.

Finally, the method of separation by means of aluminium chloride recently suggested by Leroide¹⁾ should be mentioned.

Thujone.



Thujone, $\text{C}_{10}\text{H}_{16}\text{O}$, occurs in two physically isomeric forms, namely as laevogyrate α -thujone and as dextrogyrate β -thujone (the tanacetone of Semmler). These two modifications are not optical antipodes. They can be clearly distinguished by means of their semicarbazones, and by treatment with alkali can be converted partly into each other.²⁾ Thujone was discovered simultaneously by Wallach³⁾ and Semmler;⁴⁾ the laevogyrate thujone by Wallach in thuja oil, the dextrogyrate thujone by Semmler in tansy oil. To the latter ketone Semmler applied the name tanacetone, whereas Wallach named this dextrogyrate modification β -thujone.

In addition to the oils already mentioned, α -thujone occurs in the leaf oil of *Thuja plicata*, in oil of sage, and in the oil of

¹⁾ Scientific and Industrial Bulletin of Roure-Bertrand Fils October 1909, 39; Report of Schimmel & Co. April 1910, 184.

²⁾ Wallach, Liebig's Annalen 336 (1904), 249.

³⁾ Liebig's Annalen 273 (1893), 99.

⁴⁾ Berl. Berichte 25 (1892), 3343.

Artemisia Barrelieri; β -thujone in oil of sage, in the oil of *Artemisia Barrelieri*, and particularly in oil of wormwood. From oils rich in thujone, such as tansy oil and the oil of *Artemisia Barrelieri*, the ketone can readily be separated in the form of its bisulphite addition product, which, upon decomposition with soda, yields pure thujone. For the preparation of the acid sulphite addition product, ammonium bisulphite is used, some alcohol is added to the mixture, which is set aside for some time and is frequently shaken.

Thujone is a colorless liquid with a pleasant, refreshing odor. For the ketone regenerated from the bisulphite addition product or from the semicarbazone, Wallach found the following constants:¹⁾

$d_{15} 0.9175$; $n_D 1.45109$; $d_{20} 0.916$; $n_D 1.4507$.

For α -thujone regenerated from the semicarbazone by means of dilute sulphuric acid, Wallach²⁾ found:

B. p. 200 to 201°; $d 0.912$; $\alpha_D -5.13'$; $n_D 1.4503$.

When phthalic acid anhydride was used for the regeneration an optical rotation $[\alpha]_D -10.23'$ was observed. For β -thujone, obtained from the semicarbazone, $[\alpha]_D -76.16'$ was observed. When acted upon with alkali, α -thujone is very readily changed to β -thujone, a change that must not be overlooked in the attempt to identify a natural thujone.

Thujone is a saturated ketone, nevertheless it is readily acted upon by permanganate. Bromine produces substitution products.

As already pointed out thujone differs in its behavior from camphor and fenchone in the formation of an acid sulphite addition product. With hydroxylamine it yields an oxime³⁾ which melts at 54 to 55° and which corresponds to β -thujone, whereas the oxime of α -thujone is liquid. When acted upon by phosphorus pentachloride, the crystalline oxime is changed to an isoxime⁴⁾ melting at 90°, and, when heated with dilute alcoholic sulphuric acid,

¹⁾ Berl. Berichte 28 (1895), 1965.

²⁾ Liebig's Annalen 336 (1904), 263.

³⁾ Wallach, Liebig's Annalen 277 (1893), 159; Semmler, Berl. Berichte 25 (1892), 3344.

⁴⁾ Wallach, Liebig's Annalen 286 (1895), 94; 336 (1904), 270.

into carvacrylamine.¹⁾ With semicarbazide solution,²⁾ α -thujone yields a semicarbazone that melts at 186 to 188°. There exists also an amorphous modification which melts at about 110°. From β -thujone a hexagonal semicarbazone, melting at 174 to 175°, can be derived which changes spontaneously into a stable rhombic form that melts at 170 to 172°.

Upon reduction thujone is changed to thujyl alcohol, $C_{10}H_{18}O$, the corresponding secondary alcohol,⁴⁾ which has already been described on p. 397.

When oxidized with permanganate in the cold, thujone yields a saturated ketonic acid $C_{10}H_{16}O_3$,⁵⁾ the α -thujaketonic acid, which melts at 75 to 76°. When heated or distilled *in vacuo*, it is readily changed into the isomeric, unsaturated β -thujaketonic acid, which melts at 78 to 79°. When acted upon by hypobromite, the corresponding dicarboxylic acids $C_9H_{11}O_4$ result,⁶⁾ of which the α -acid melts at 141.5°, the β -acid at 116 to 118°. Upon destructive distillation, both ketonic acids yield thujaketone,⁷⁾ $C_9H_{14}O$, the odor of which resembles that of methylheptenone. As "Abbau" product, both ketones also yield δ -(α -)dimethyl-lævulinic acid, which melts at 32°.⁸⁾

If thujone is heated for a long time to 280° in sealed tubes, it is changed into an isomeric, unsaturated ketone $C_{10}H_{16}O$, the odor of which resembles that of carvone, and which has been named carvotanacetone.⁹⁾ Judging from the reduction in the angle of rotation, this change appears to take place even upon prolonged boiling. Another isomeric, unsaturated ketone, *isothujone*, results when thujone is moderately heated with dilute sulphuric acid.¹⁰⁾

¹⁾ Semmler, Berl. Berichte 25 (1892), 3352.

²⁾ Wallach, Liebig's Annalen 286 (1895), 94; 306 (1904), 270.

³⁾ This melting point applies to the perfectly pure compound only. Commonly 184.5 to 186° is found.

⁴⁾ Semmler, Berl. Berichte 25 (1892), 3344.

⁵⁾ Semmler, *Ibidem* 3347; Wallach, Liebig's Annalen 272 (1893), 111; Berl. Berichte 30 (1897), 423.

⁶⁾ Semmler, *Ibidem* 3346.

⁷⁾ Wallach, Liebig's Annalen 272 (1893), 116; 275 (1893), 164.

⁸⁾ Tiemann and Semmler, Berl. Berichte 30 (1897), 429; 31 (1898), 2311.

⁹⁾ Semmler, Berl. Berichte 27 (1889), 895.

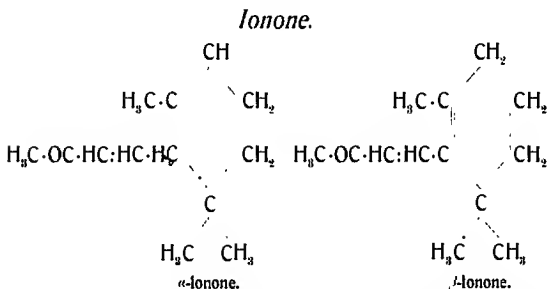
¹⁰⁾ Wallach, Liebig's Annalen 286 (1895), 101; 323 (1902), 334; Berl. Berichte 28 (1895), 1959; 30 (1897), 26.

Upon reduction, *isothujone* is converted into the saturated *thujamenthol*. When boiled with a solution of ferric chloride, *thujone* is converted into *carvacrol*.

The structural formula given above was based by Semmler¹⁾ on the physical and chemical properties of *thujone*. Somewhat later it was accepted by Wallach.²⁾

The tribromide is best suited for the characterization of *thujone*. According to Wallach³⁾ it is prepared by adding at once 5 ccm. of bromine to a solution of 5 g. of *thujone* in 30 ccm. petroleum ether contained in large beaker. After a few seconds a rather violent reaction sets in accompanied by the evolution of hydrogen bromide. Upon evaporation of the solvent, the tribromide separates gradually as a crystalline mass which is freed from adhering oil by washing it with cold alcohol, and which can be recrystallized from hot acetic ether. The melting point of the pure compound lies at 121 to 122°. When acted on with methylalcoholic or ethylalcoholic potassium hydroxide solution, the phenols $C_{10}H_{11}Br(OH)(OCH_3)$ and $C_{10}H_{11}Br(OH)(OC_2H_5)$ respectively result. The former melts at 156 to 157°, the latter at 144 to 145°.

For the identification of the α - and β -modifications of *thujone* the semicarbazones described above are made use of.



This violet perfume of the formula $C_{15}H_{26}O$, the presence of which in nature has not yet been definitely established, was

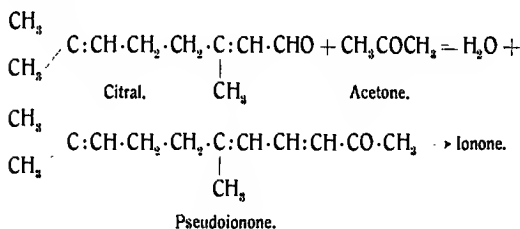
¹⁾ Berl. Berichte 33 (1900), 275, 2454.

²⁾ Liebig's Annalen 323 (1902), 371.

³⁾ *Ibidem* 275 (1893), 179; 286 (1895), 109.

first obtained synthetically in 1893 by Tiemann and Krüger.¹⁾ Since then a considerable number of patents have been issued for the preparation of "violet ketones" *i. e.*, for that of ionone and its homologues.

The preparation of ionone is based on the condensation of the olefinic aldehyde citral with acetone. In the presence of alkalis the olefinic ketone, the pseudoionone of the formula $C_{13}H_{20}O$, results. In the presence of acid reagents, whether weak or strong, either at low or higher temperatures, this pseudoionone rearranges itself to the cyclic, isomeric ketone, the ionone.



The inversion of pseudoionone to ionone may be brought about more particularly by concentrated sulphuric acid, phosphoric acid, formic acid, and oxalic acid, also by dilute mineral acids and solutions of acid alkali sulphates, even by neutral salts such as sodium acetate and magnesium sulphate in an autoclave. In the case of the concentrated acids, the action should be restricted to a lower temperature, also to a shorter time. In the case of dilute acids and other substances, prolonged heating is required. In all of these reactions a mixture of two isomers, the α - and β -ionone, is formed.

If in place of acetone its homologues be employed, the corresponding homologues of pseudoionone are formed, which can be inverted into the isomeric ionone derivatives as stated above.

Reduced pseudoionones and homologues thereof are obtained by the condensation of citronellal with acetone and its homologues. These in turn can be isomerised to the corresponding ionones

¹⁾ Berl. Berichte 26 (1893), 2691.

and homologues by means of acids. Acetyl pseudoionones and acetyl ionones have also been prepared. As the most important representative of the cyclocitral series, ionone is of considerable scientific interest.

PSEUDOIONONE. Although this ketone does not react immediately with sodium acid sulphite solution at ordinary temperature, it does combine with it upon prolonged heating to a hydrosulphonic acid derivative which is soluble.¹⁾ This compound can be utilized for the preparation of pure pseudoionone. The solution is first shaken repeatedly with ether or other immiscible solvent for the purpose of removing aldehyde resins or other impurities. The ketone is then regenerated with the aid of alkali at ordinary or lower temperature.

Pseudoionone is a light yellow, strongly refractive, somewhat viscid oil, the odor of which is little characteristic. Its constants are:

B. p. 143 to 145 (12 mm.); d_{20}^{20} , 0.8980; n_D^{20} , 1.53346.

Of characteristic derivatives the *p*-bromphenylhydrazone, melting at 102 to 104°, may be mentioned.

IONONE. As already pointed out, the production of ionone results invariably in the formation of a mixture of two isomers. If concentrated sulphuric acid be used, or if dilute sulphuric acid be allowed to react for a longer period²⁾, the resulting mixture consists largely of β -ionone. If, however, the inversion be brought about by concentrated phosphoric or formic acids, α -ionone results almost exclusively. Toward acid sulphite solution ionone behaves like pseudoionone. The resulting hydrosulphonic acid can be well utilized for the purification of ionone.

Freshly distilled ionone is a colorless oil with a decided odor of cedarwood. It is only in dilute solution, e. g. in alcohol, that its odor of violets, reminding at the same time somewhat of grape blossoms, becomes apparent. Noteworthy is also the property of ionone to benumb the sense of smell.

¹⁾ Tiemann, Berl. Berichte 31 (1898), 842.

²⁾ Tiemann, Berl. Berichte 31 (1898), 868, 870.

Even the ionones purified through the hydrosulphonic addition products vary more or less in their α - and β -ionone content according to the reagents employed in their isomerization. Hence their physical constants vary appreciably. For a pure ionone, consisting however of a mixture of the two isomers, Tiemann¹⁾ records the following constants:

B. p. 126 to 128° (10 mm.); d_{20} , 0,9351; n_D , 1,507;

whereas Schimmel & Co. observed the following on their own products:

B. p. 104 to 109° (4 to 5 mm.); d_{18} , 0,9350 to 0,9403; d_{20} , 0,9335; n_{D20} , 1,50335 to 1,50510; soluble in 2,5 to 3,0 vols. of 70 percent. alcohol.

As to odor, the differences between α - and β -ionone are but slight, yet nevertheless recognizable by the expert. That of α -ionone is fresher and more fragrant than that of its isomer, which is rather strong and reminds more of the odor of the leaves of the violet. Hence the former is preferred.

To α -IONONE Tiemann²⁾ assigns the following properties:

B. p. 123 to 124° (11 mm.); d_{20} , 0,932; n_D , 1,4980.

Chuit³⁾ found:

B. p. 127,6° (12 mm.); d_{18} , 0,9338; $n_{D17,2}$, 1,50001.

The *p*-bromophenylhydrazone, which is best suited for the characterization of α -ionone, melts at 142 to 143°. It is prepared in glacial acetic acid solution and recrystallized from dilute methyl alcohol or ligroin. The semicarbazone melts at 107 to 108°, respectively at 137 to 138°, the thiosemicarbazone at 121°, the oxime at 89 to 90°.

For pure β -IONONE Tiemann⁴⁾ determined the following constants:

B. p. 127 to 128,5° (10 mm.); d_{17} , 0,946; n_{D17} , 1,521;

¹⁾ Berl. Berichte 31 (1898), 851.

²⁾ Berl. Berichte 31 (1898), 876.

³⁾ Rev. gén. de Chim. 6 (1903), 432; Chem. Zentralbl. 1904, I. 280.

⁴⁾ Berl. Berichte 31 (1898), 871, 879.

Chuit¹⁾ the following: B. p. 134,6° (12 mm.); d_{18}^0 , 0,9488; $n_{D17,5}^0$, 1,52008.

β -Ionone can best be identified by means of its semicarbazone²⁾ which melts at 148 to 149°. Its *p*-bromphenylhydrazonc melts at 116 to 118°, its thiosemicarbazonc at 158°, its hydrazone at 104 to 105°. The oxime is liquid.

Concentrated sulphuric acid inverts α -ionone to β -ionone. Inversely, β -ionone can be changed, though more difficultly, to α -iononc by means of alcoholic potassa.

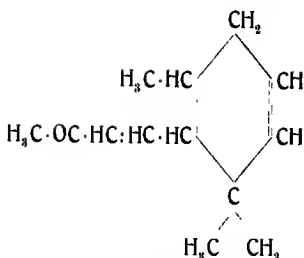
The physical constants of commercial ionone do not afford a definite clue as to its purity. In order to test such a preparation as to its purity, the by-products that result during its manufacture should be removed.

For this purpose the oil to be examined is boiled for 10 to 15 hours with thrice its weight of sodium acid sulphite solution in which the free sulphurous acid has been neutralized with dilute soda solution. The duration is dependent on the reaction of the ionone with the bisulphite. According to Schimmel & Co., the addition of alcohol suggested by Schmidt,³⁾ is not necessary. In order to remove those substances that have not combined with the acid sulphite, the solution after having been diluted with water is extracted four times with ether. If the ionone is comparatively pure, the addition of water will cause but a slight turbidity, if impure the separation of an oil. Should the separated portion smell of iononc, a second treatment with acid sulphite is necessary. The difference between the amount originally used and the amount extracted is computed as ionone. Some idea as to the relative proportions of α - and β -ionone present can be obtained from the physical constants of the mixed ionones separated from the acid sulphite addition product by means of lyc, also by means of the semicarbazonc and *p*-bromphenylhydrazonc.

¹⁾ *Loc. cit.*

²⁾ For the purification and separation of the ionone semicarbazones compare Tiemann, Berl. Berichte 31 (1898), 875, 1736.

³⁾ Zeitschr. f. angew. Chem. 13 (1900), 189.

Irone.

Irone, $\text{C}_{18}\text{H}_{20}\text{O}$, has thus far been found only in orris oil, the German "Veilchenwurzelöl" (from *Iris florentina*, *I. pallida*, *I. germanica*). Tiemann and Krüger¹⁾ were the first to isolate it from orris root and to recognize it as a cyclic ketone isomeric with ionone. They obtained it by extracting orris root with organic solvents and distilling the evaporated extract with steam. Since liquid orris oil is to be had in the market, irone can be obtained from it by fractional distillation. It collects in fraction 105 to 120° obtained under a pressure of 4 mm. It is purified through the oxime or phenylhydrazone from either of which it can be conveniently regenerated.

Irone is a colorless oil. Its peculiar odor,²⁾ which reminds of certain species of violets, is brought out only in extreme dilution. For the carefully purified ketone, Tiemann and Krüger (*loc. cit.*) report the following constants:

B. p. 144° (16 mm.); $d_{20} = 0.939$; α_D , abt. + 40°; $n_{D20} = 1.50113$.

For a preparation isolated from the sodium salt of the phenylhydrazine sulphonic acid derivative,³⁾ Schimmel & Co. observed the following constants:

B. p. 111 to 112° (2 mm.); $d_{15} = 0.9391$; α_D , + 33° 31'; $n_{D20} = 1.50173$.

For the characterization of irone its *p*-bromphenylhydrazone is well suited. According to Schimmel & Co. it melts at 174

¹⁾ Berl. Berichte 26 (1893), 2675.

²⁾ Tiemann's observation that irone possesses a pungent odor is not correct.

³⁾ For the technique to be observed in the preparation of this compound compare the expert testimony given by v. Baeyer, Berlin 1899, p. 22.

to 175°.) It is crystallized from methyl alcohol. According to Chuit²⁾ the thiosemicarbazone melts at 181°. The oxime, which melts at 121.5°, crystallizes with difficulty. The melting point of 70 to 80°, found for amorphous semicarbazone³⁾ by Schimmel & Co., gives rise to the suspicion that this is a mixture of isomeric derivatives.

When irone is acted upon by hydrogen iodide, dehydration and ring-formation take place and irene, $C_{13}H_{18}$, is formed, which hydrocarbon is isomeric with ionene.

It is only recently that Merling and Welde⁴⁾ have succeeded in preparing irone synthetically. This synthesis is based on the formation of *A*¹-cyclocitral which, upon condensation with acetone, yields irone. Isopropylideneacetoacetic ester is condensed with sodium acetoacetic ester to isophorone carboxylic acid ester. From this *d*-chlorcyclogeranioldiene carbonic acid and *A*¹-cyclogeranic acid are obtained. According to a special method⁵⁾ the latter is converted into *A*¹-cyclocitral.

PHENOLS AND PHENOL ETHERS.

The phenols and their ethers occur frequently in volatile oils. On account of the practical importance which many have acquired, they are prepared on a large scale. Thus thymol finds application on account of its antiseptic properties, anethol is used in pharmacy and in the production of liqueurs, eugenol and safrol are basal substances from which vanillin and heliotropin are manufactured.

The lower homologues of the series in question occur but rarely in volatile oils.

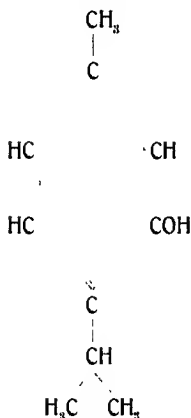
¹⁾ Tiemann and Krüger mention 168 to 170° as the melting point.

²⁾ Rev. gén. de Chim. 6 (1903), 433; Chem. Zentralbl. 1904, I. 281.

³⁾ Compare Berl. Berichte 28 (1895), 1755.

⁴⁾ Liebig's Annalen 306 (1909), 119.

⁵⁾ Merling, Berl. Berichte 41 (1908), 2064.

Thymol.

Thymol (*isopropyl-m-cresol*), $\text{C}_{10}\text{H}_{11}\text{O}$, is frequently accompanied by carvacrol. In addition to *p*-cymene and terpenes, it constitutes the larger part of ajowan oil. It occurs also in the oils of *Ocimum viride*, *Monarda punctata*, *Satureja Thymbra*, *Origanum floribundum*, thyme, *Thymus capitatus*, wild thyme, *Mosla japonica* and probably also in Canadian mint oil and in culina oil. Occasionally it separates from the oils at ordinary temperature.

As a source for thymol on a large scale, ajowan oil is mostly used.

Artificially it can be prepared in a variety of ways. Of interest is its production from dibrommenthone by splitting off hydrogen bromide by means of quinoline.¹⁾

Thymol consists of colorless, transparent, monoclinic or hexagonal crystals, the odor of which reminds of thyme. They melt at 50.5 to 51.5° and boil at 232° (752 mm., the entire mercury thread in the vapor). Thymol crystals sink in water, hence have a density greater than 1. Liquid thymol, however, floats on the surface of water. It can be cooled considerably below its congealing point without solidifying. In

¹⁾ Beckmann and Eickelberg, Berl. Berichte 29 (1896), 420.

connection with liquid thymol, Perkin¹⁾ has observed the following densities:

d_4 , 0.9872; d_{18} , 0.9790; d_{20} , 0.9757; d_{25} , 0.9723; d_{60} , 0.9624.

As for the index of refraction ($n_{D21.4}$) Nasini and Bernheimer²⁾ record 1.51893. Schimmel & Co. found:

d_{18} , 0.9760 and n_{D20} , 1.52269 (supercooled).

Thymol is but sparingly soluble in water (1:1200) and in glycerin (1:1000), more so in paraffin oil (about 1:20), readily in alcohol, ether, chloroform, benzene, glacial acetic acid, volatile and fatty oils. In distinction to carvacrol, the alcoholic solution is not colored by ferric chloride. However, the aqueous solution of thymol sulphonic acid, $C_8H_7(SO_3H)(CH_3)(C_6H_7)(OH)$ resulting upon the solution of thymol in concentrated sulphuric acid produces a violet color with ferric chloride.

As a phenol, thymol forms water soluble "salts" with the alkalis. Hence it can be shaken out from its ethereal solution by means of 5 to 10 p. c., aqueous solutions of alkali. This property is utilized for the quantitative estimation of thymol. (Comp. the chapter on "The estimation of volatile oils" under Phenol determinations.)

Of thymol derivatives the following may here be mentioned: the phenylurethane, m. p. 107°, and the nitroso compound, m. p. 160 to 162°³⁾ which results from the action of nitrous acid upon thymol. Upon oxidation it can be converted into thymoquinone.

Like its derivatives, thymol possesses decided disinfecting properties. These are, however, destroyed in the presence of oxidizing ferments in the presence of air.⁴⁾

Ethers from neither thymol nor carvacrol have been found in volatile oils. Guillaumin⁵⁾ has prepared and described isomerides of thymol, but as yet it is not known whether or not these occur in volatile oils.

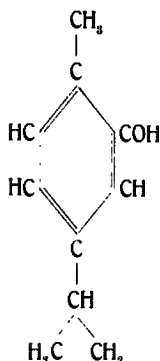
¹⁾ Journ. chem. Soc. 69 (1896), 1183.

²⁾ Gazz. chim. ital. 15 (1885), 59; Jahresber. d. Chem. 1885, 314.

³⁾ For the method of preparation comp. Klages, Berl. Berichte 32 (1899), 1518.

⁴⁾ Cousin and Hérissay, Journ. de Pharm. et Chim. VI. 26 (1907), 487.

⁵⁾ *Étude chimique et pharmacologique des thymols synthétiques dérivés des acides crésotiniques.* Inaug. Dissert., Paris 1909; Report of Schimmel & Co. April 1909, 136.

Carvacrol.

Carvacrol (*isopropyl-o-cresol*), $C_{10}H_{14}O$, occurs principally in labiate oils. Thus far its presence has been demonstrated in camphor oil, schinus oil, the oils of *Monarda punctata* (?), *M. fistulosa*, *M. citriodora*, *Satureja hortensis*, *S. montana*, *Origanum vulgare*, in the origanum oils from Trieste, Smyrna, Cyprus, and Syria, in the oils of thyme and wild thyme, and in the oil of *Thymus capitatus* (?).

Artificially carvacrol can be obtained from its isomeride carvone by treating this ketone with potassa, sulphuric acid, or phosphoric acid; from camphor by heating it with iodine; from cymene sulphonc acid by fusion with potassa; also from a number of terpene derivatives, thus from thujone, carvenone, carvotanacetone, dihydrocarvone, nitrosopinene, ketoterpin, and terpinene erythrite.

Freshly distilled, carvacrol is a colorless, viscid oil which becomes yellowish in the course of time, and which congeals in the cold. Its alcoholic solution is colored green by ferric chloride. The following constants are recorded:

M. p. $+0.5$ to $+1^{\circ}$; b. p. 236 to 237° (corr.); d_{15}° , 0.981 ; n_D^{20} , 1.525 .¹⁾

B. p. 119° (16 mm.); d_{20}° , 0.9782 ; n_D^{20} , 1.5228 .²⁾

¹⁾ Jahns, Berl. Berichte 15 (1882), 817.

²⁾ Semmler, Berl. Berichte 25 (1892), 3353.

For carvacrol from origanum oil Gildemeister found:¹⁾

M. p. $+0,5^{\circ}$; b. p. 235,5 to 236,2' (742 mm.); $d_{15^{\circ}}$ 0,980;
 $d_{20^{\circ}}$ 0,976; $n_{D20^{\circ}}$ 1,52338;

and for carvacrol prepared from carvone:

M. p. $+0,5^{\circ}$; b. p. 236 to 236,5' (742 mm.); $d_{15^{\circ}}$ 0,983;
 $d_{20^{\circ}}$ 0,979; $n_{D20^{\circ}}$ 1,52295.

In connection with products made on a large scale, Schimmel and Co. observed:

$d_{15^{\circ}}$ about 0,98; $n_D + 0^{\circ}$; $n_{D20^{\circ}}$ 1,523 to 1,524; soluble in 3 vols. of 70 p. c. alcohol.

Like thymol, carvacrol can be extracted from oils with aqueous alkali and determined quantitatively (see the chapter "Examination of volatile oils" under Phenol determination): It should be remembered, however, that carvacrol can be completely extracted from its alkaline solution by shaking with ether.²⁾ It can likewise be distilled from strongly alkaline solutions with steam, a property which, so far as phenols are concerned, is shared only by thymol.³⁾

Prolonged moderate heating with caustic potassa converts carvacrol into *isohydroxycuminic acid*, $(CH_3)_2CHC_6H_4(OH)CO_2H$ (4-metho ethyl-phenol-2-methyl acid-1),⁴⁾ which is readily volatile with water vapors and which melts at 93° . Chromic acid mixture oxidizes it to thymoquinone, which crystallizes in yellow plates that melt at $45,5^{\circ}$.⁵⁾ When reduced according to Sabatier and Senderens a mixture of two isomeric alcohols, α - and β -carvacromenthol, is obtained. The latter yields *i*-tetrahydrocarvone upon oxidation.⁶⁾

For the identification of carvacrol, the phenylurethane,⁷⁾ m. p. 140° , and nitroso carvacrol are well suited. The latter is best prepared according to the directions of Klages.⁸⁾ To a solution of carvacrol in four times its volume of alcoholic hydro-

¹⁾ Arch. der Pharm. 233 (1895), 188.

²⁾ Jahns, Berl. Berichte 15 (1882), 817.

³⁾ Klages, *ibidem* 32 (1899), 1517.

⁴⁾ Jacobsen, Berl. Berichte 11 (1878), 573, 1061.

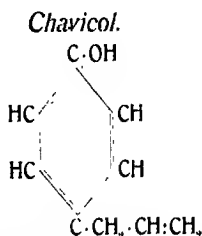
⁵⁾ Reychler, Bull. Soc. chim. III. 7 (1892), 34; Chem. Zentralbl. 1892, I. 380.

⁶⁾ Brunel, Compt. rend. 141 (1905), 1245; 145 (1907), 1427.

⁷⁾ Goldschmidt, Berl. Berichte 26 (1893), 2086, footnote; comp. also Gildemeister, Arch. der Pharm. 233 (1895), 188.

⁸⁾ Berl. Berichte 32 (1899), 1518.

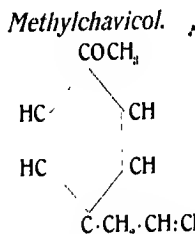
chloric acid, saturated at 0° , and kept cool with ice, a concentrated solution of sodium nitrite is added drop by drop. Within a few minutes, the entire liquid congeals to a thick mass of nitroso compound. This is first washed with water and then recrystallized from dilute alcohol. It crystallizes in yellow needles that melt at 153° . The benzoyl compound of nitroso carvacrol melts at 110° .



Chavicol (*p*-allylphenol), $C_9H_{10}O$, occurs in some of the betel leaf oils, also in oil of bay, and possesses strongly antiseptic properties.

It is a colorless liquid that boils at about 237° . According to Eykman¹⁾ $d_{15} = 1.033$ and $n_D = 1.5441$.

For its identification the crude phenols from betel leaf oil, separated by means of aqueous alkali, are fractionated. Fraction 235 to 240° is methylated and thus converted into methylchavicol which can easily be identified. The aqueous solution of chavicol is colored an intensive blue by ferric chloride, the alcoholic solution scarcely blue.



Methylchavicol (estragol, *iso*anethol, *p*-allylanisol), $C_{10}H_{12}O$, was first found in anise bark oil, later also in staranise oil,

¹⁾ Berl. Berichte 23 (1890), 862.

For carvacrol from origanum oil Gildemeister found:¹⁾

M. p. $+0,5^{\circ}$; b. p. 235,5 to 236,2' (742 mm.); $d_{15^{\circ}}$ 0,980;
 $d_{20^{\circ}}$ 0,976; $n_{D20^{\circ}}$ 1,52338;

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¹⁾ Arch. der Pharm. 233 (1895), 188.

²⁾ Jahns, Berl. Berichte 15 (1882), 817.

³⁾ Klages, *ibidem* 32 (1899), 1517.

⁴⁾ Jacobsen, Berl. Berichte 11 (1878), 573, 1061.

⁵⁾ Reychler, Bull. Soc. chim. III. 7 (1892), 34; Chem. Zentralbl. 1892, I. 380.

⁶⁾ Brunel, Compt. rend. 141 (1905), 1245; 145 (1907), 1427.

⁷⁾ Goldschmidt, Berl. Berichte 26 (1893), 2086, footnote; comp. also Gildemeister, Arch. der Pharm. 233 (1895), 188.

⁸⁾ Berl. Berichte 32 (1899), 1518.

longistylis and in kobuschi oil has likewise been demonstrated. It is usually obtained from anise oil, staranise oil or fennel oil, ether by freezing the oils themselves or the corresponding fractions. Synthetically it has also been obtained in several ways.

Anethol constitutes a white, crystalline mass with an odor of anise and with an intensely sweet taste. It melts to a colorless, optically inactive, strongly refractive liquid. The following properties have been recorded:

M. p. 21° ; d_{25}° , 0,986; n_{D18}° , 1,56149;¹⁾ $d_{11.5}^{\circ}$, 0,999; n_D , 1,5624.²⁾

In connection with anethol produced on a large scale, Schimmel & Co. observed the following values:

M. p. 22,5 to 23° ; congealing point 21 to 22° ; b. p. 233 to 234° (751 mm.); d_{25}° , 0,984 to 0,986; n_{D25}° , 1,559 to 1,561; soluble in 2 to 3 vols. of 90 p. c. alcohol.

Of characteristic bromine derivatives of anethol, the anethol dibromide, $C_6H_4 \cdot OCH_3 \cdot C_6H_4Br_2$, m. p. 67° ,³⁾ and the monobrom anethol dibromide, $C_6H_4BrOCH_3 \cdot C_6H_4Br_2$, m. p. 107 to 108° ,⁴⁾ may be mentioned. These are formed by the action of bromine on anethol under varying conditions. By the action of alcoholic potassa on anethol dibromide in the cold, anethol glycol, $C_6H_4 \cdot OCH_3 \cdot C_6H_4(OH)_2$,⁵⁾ results. When acted upon with 20 p. c. sulphuric acid, this is converted to anise ketone. The same glycol is likewise formed by the action of mercuric acetate upon anethol.⁶⁾ Anethol nitrite, $C_{10}H_{12}O \cdot N_2O_3$, m. p. 121° , and anethol nitrosochloride, $C_{10}H_{12}O \cdot NOCl$, m. p. 127 to 128° , should also be mentioned.

Dilute nitric acid oxidizes anethol to anisic aldehyde, chromic acid oxidizes it to anisic aldehyde and anisic acid, potassium permanganate to *p*-methoxyphenylglyoxylic acid $C_6H_4 \cdot (OCH_3)^{11}$. $CO \cdot COOH^{12}$, m. p. 89° , the oxime of which melts at 145 to 146° .

¹⁾ Stohmann, Sitzungsber. d. Akad. d. Wiss. Leipzig 1892, 318.

²⁾ Eykman, Berl. Berichte 23 (1890), 862.

³⁾ Hell and v. Günthert, Journ. f. prakt. Chem. II. 52 (1895), 198.

⁴⁾ Hell and Gärtner, Journ. f. prakt. Chem. II. 51 (1895), 424; Hell and v. Günthert, loc. cit. 194.

⁵⁾ Varenne and Godefroy, Compt. rend. 140 (1905), 591.

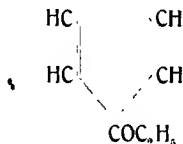
⁶⁾ Balbiano and Paolini, Berl. Berichte 35 (1902), 2997.

When acted upon by light and air,¹⁾ anethol gradually loses its capacity to crystallize and finally no longer even congeals. At the same time it becomes viscid, acquires a yellow color and an unpleasant, bitter taste, both of which no longer remind of anise. This change is accompanied by an increase in the solubility and an increase in specific gravity which may rise above 1. These phenomena are attributed to the formation of oxidation²⁾ (anisic aldehyde, anisic acid) and other products. Of the latter de Varda³⁾ has isolated a compound named photoanethol which he regards as a polymer of anethol. According to Hoering and Gräler,⁴⁾ de Varda's interpretation is not correct, but photoanethol is regarded as identical with di-*p*-methoxystilbene. This substance is characterized by its insolubility and is possibly the cause of the turbidity produced in freshly prepared anethol upon standing.

Recrystallized from glacial acetic acid and benzene, di-*p*-methoxystilbene is obtained in shiny leaflets that melt at 214 to 215°, which show a blue fluorescence both in the solid condition and in solution. Probably di-*p*-methoxystilbene is not formed directly from anethol but from the intermediate anisic aldehyde.

p-Hydroquinone ethyl ether.

COH



p-Hydroquinone ethyl ether (*p*-hydroxyphenetol), $\text{C}_8\text{H}_{10}\text{O}_2$, occurs in small amount in staranise oil. It can be obtained synthetically by boiling *p*-diazophenetolsulphate with dilute sul-

¹⁾ According to Grimaux anethol also loses its capacity to crystallize upon prolonged heating. Bull. Soc. chim. III. 15 (1896), 778.

²⁾ Report of Schimmel & Co. October 1904, 11.

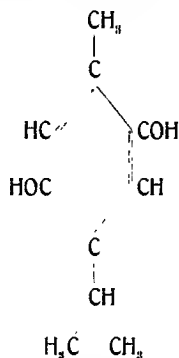
³⁾ Gazz. chim. ital. 21 (1891), 183; Chem. Zentralbl. 1891, I. 788.

⁴⁾ Berl. Berichte 42 (1909), 1204.

phuric acid,¹⁾ or from hydroquinone by heating it with ethyl iodide and potassium hydroxide using a reflux condenser.²⁾

The synthetic product consists of thin leaflets with satiny lustre, which are readily soluble in hot water, melt at 66° and boil at 246 to 247°.

Thymohydroquinone.



Thymohydroquinone, $\text{C}_{10}\text{H}_{14}\text{O}_2$, has been found in the oil of *Callitris quadrivalvis*, Algerian fennel oil (?) and in the oil of *Monarda fistulosa*. Artificially it is obtained by the reduction of thymoquinone with sulphurous acid.³⁾

Thymohydroquinone occurs in four-sided, shiny prisms. According to Carstanjen⁴⁾ they melt at 139.5°, according to Ciamician and Silber⁵⁾ at 143°. According to the latter authorities thymohydroquinone boils at 290°. It is somewhat readily soluble in hot water, but difficultly in cold water. When oxidized it is changed to thymoquinone.

The dimethyl ether of thymohydroquinone is the principal constituent of arnica root oil, also of ayapana oil. It boils at 248 to 250°; $d_{20} = 0.998$.⁶⁾

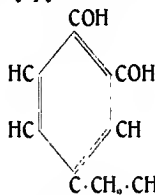
¹⁾ Hantzsch, Journ. f. prakt. Chem. II. 22 (1880), 462.

²⁾ Wichelhaus, Berl. Berichte 12 (1879), 1501, footnote; comp. Hesse, Liebig's Annalen 200 (1880), 254.

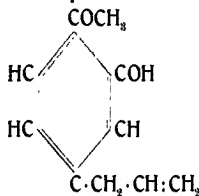
³⁾ Carstanjen, Journ. f. prakt. Chem. II. 3 (1871), 54.

⁴⁾ Atti della Reale Accademia dei Lincei Rendiconti (5) 10, I. (1901), 96.

⁵⁾ Reychler, Bull. Soc. chim. III. 7 (1892), 33.

Allylpyrocatechin.

The presence of allylpyrocatechin, $\text{C}_9\text{H}_{10}\text{O}_2$, in Javanese betel leaf oil was demonstrated by Schimmel & Co.¹⁾ Previously this phenol had not been known to exist in the vegetable kingdom, neither had it been prepared synthetically. It is one of the phenols extracted by means of dilute caustic soda solution from fraction 137 to 139° (4 mm.). Crystallized from benzene and petroleum ether, it is obtained in long colorless, fitt-like needles which melt at 48 to 49° and boil at 139° (4 mm.). The odor is but faint, reminding somewhat of creosote. In water and alcohol it is readily soluble. The alcoholic solution is colored a deep green by ferric chloride. The alkaline solution of the phenol quickly assumes a dark red color. The dibenzoyl compound, prepared according to Schotten-Baumann, melts at 71 to 72°. The diacetyl compound is a colorless oil which boils at 229° (157° at 7 mm.). When methylated with dimethyl sulphate, the phenol is converted into methyleugenol.

Betelphenol.

Betelphenol²⁾ (allylguaiacol), $\text{C}_{10}\text{H}_{12}\text{O}_2$, has thus far been found only in betel oil, from which it can be isolated in the usual manner

¹⁾ Report of Schimmel & Co. October 1907, 16.

²⁾ The name betelphenol, given to this compound by its discoverers, was later changed to chavibetol by others.

by shaking it out with caustic soda solution. It is a strongly refractive solution characterized by the following properties:

B. p. 254 to 255°, 131 to 133° (12 to 13 mm.); d_{15}^4 1.067.¹⁾

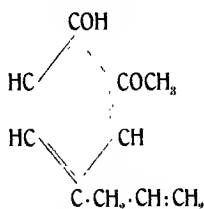
B. p. 107 to 109° (4 mm.); d_{15}^4 1.0690; n_{15D}^{20} 1.54134.²⁾

In a freezing mixture it congeals to a crystalline mass which melts at + 8.5°.

For its identification the benzoyl compound, m. p. 49 to 50° is utilized. The acetyl compound melts at - 5°; b. p. 275 to 277°.

In alcoholic solution, betelphenol gives an intensively blue-green color with ferric chloride.

Eugenol.



Eugenol, $\text{C}_{10}\text{H}_{12}\text{O}_2$, an isomer of position to betelphenol is found widely distributed, especially among the *Myrtaceæ* and *Lauraceæ*. In largest amount it is found in oil of cloves and oil of clove stems. It also occurs in the oils of calamus, galangal, *Asarum arifolium*, *A. Blumei*, Japanese staranisc, kobuschi, ylang-ylang, cananga (from yellow blossoms), nutmeg, boldo leaves, cinnamon leaves, cinnamon root, the bark of *Cinnamomum pedatinerviium*, *C. pedunculatum*, in the oil from Seychelles cinnamon bark, in the oils from the leaves and stem of *Cinnamomum Loureirii*, in the oils of camphor, culilawan, clove bark (?), sassafras, massoy bark, laurel leaves, apopin, Californian laurel, rose, *Geum urbanum*, cassie buds, myrrh, cascarilla, canella alba, pimenta, bay, Bermuda bay berries, Japanese basilicum, in the oil of a species of *Basilicum* from Mayotta, and in patchouli.

¹⁾ Bertram and Gildemeister, Journ. f. prakt. Chem. II, 39 (1889), 350.

²⁾ Report of Schimmel & Co. October 1907, 17.

In plants, eugenol is occasionally found in the form of a glucoside from which it can be obtained by means of hydrolysis produced by ferment action.

It is a liquid of a slightly yellowish color, with an intensive odor of cloves, and a burning taste, which, besides being optically inactive, is further characterized by the following properties:

B. p. 252° (749,5 mm.); 123° (12 to 13 mm.); $d_{11,5} 1,072$; $n_D 1,5439$.²⁾

In connection with eugenol prepared on a large scale, Schimmel & Co. observed:

$d_{15} 1,0713$ to $1,074$; $n_{D20} 1,541$ to $1,542$; soluble in 5 to 6 vols. of 50 p. c. alcohol, in 2 to 3 vols. of 60 p. c. and in 1 to 2 vols. of 70 p. c. alcohol.

In alcoholic solution, eugenol produces a blue color with ferric chloride. Upon oxidation (the best results are obtained with the acetic ester), it yields vanillin and vanillic acid, together with small amounts of homovanillic acid.

It is readily characterized by means of the benzoate, m. p. 69 to 70° , obtained with the aid of benzoyl chloride; also by the phenylurethane, m. p. $95,5^{\circ}$,³⁾ and its diphenylurethane, m. p. 107 to 108° .⁴⁾ Of its bromides, the dibromide, $C_{10}H_{12}Br_2O_2$, m. p. 80° , and the tetrabromide, m. p. 118 to 119° , should be mentioned. For the quantitative determination of eugenol see the chapter on the "Estimation of volatile oils".

Eugenol is used in perfumery as well as in pharmacy. By far the largest amounts, however, are used in the manufacture of vanillin.

Aceteugenol.

In addition to eugenol, oil of cloves, but not oil of clove stems, contains some acetoeugenol, $CH_3COOC_6H_3 \cdot C_2H_5 \cdot OCH_3$. This compound can be freed from eugenol by treating it with

¹⁾ Erdmann, Journ. f. prakt. Chem. II. 56 (1897), 146.

²⁾ Eykman, Berl. Berichte 23 (1890), 262.

³⁾ Snape, Berl. Berichte 18 (1885), 2432.

⁴⁾ Herzog, Berl. Berichte 40 (1907), 1834.

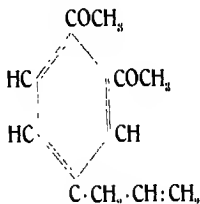
dilute alkali in the cold and can be prepared readily by boiling eugenol with acetic acid anhydride. The following constants have been found:

Erdmann:¹⁾ m. p. 29°; b. p. 281 to 282° (752 mm.); 145 to 146° (8,5 mm.); d_{18}° 1,0842 (supercooled).

Schimmel & Co.:²⁾ M. p. 29°; b. p. 142 to 143° (6 mm.); d_{18}° 1,087; n_{D20}° 1,52069.

Acethomovanillic acid, acetvanillic acid and acetvanillin result upon oxidation with potassium permanganate.

Methyleugenol.



Eugenol is frequently accompanied by its methyl ether, the methyleugenol (allylvcratrol), $\text{C}_{11}\text{H}_{11}\text{O}_2$. It occurs in citronella oil, Japanese calamus oil, matipo oil (?), betel oil, Canada snake-root oil, in the oils of *Asarum europæum* (?), champaca flowers (?), paracoto bark, in the oil from the bark of *Cinnamomum pedatinervium*, in culilawan oil, laurel oil, in California laurel oil, in the oil of cassie buds, and in the oils of *Evodia simplex*, bay, and pimenta.

Its odor reminds of that of eugenol, but is fainter. It boils at 248 to 249° (128 to 129° at 11 mm.);³⁾ d_{11}° 1,041; and n_D^{20} 1,5373.⁴⁾

In the laboratory of Schimmel & Co., the following constants were observed in connection with technical products:

d_{18}° 1,04 to 1,043; n_{D20}° 1,534 to 1,540; soluble in 4 vols. of 60 p. c. and in 1 to 2 vols. of 70 p. c. alcohol.

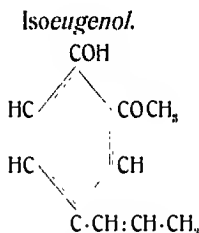
¹⁾ Journ. f. prakt. Chem. II, 56 (1897), 147.

²⁾ Report of Schimmel & Co. Oct. 1903, 30, footnote.

³⁾ Bertram and Gildemeister, Journ. f. prakt. Chem. II, 30 (1889), 354.

⁴⁾ Eykman, Berl. Berichte 23 (1890), 862.

When boiled with alcoholic potassa, methylisoeugenol results. Bromine is added with the formation of the handsome crystalline tribrommethylisoeugenol, $C_{10}H_2Br \cdot (OCH_3)_2 \cdot C_8H_8Br_2$, which melts at 78° .¹⁾ Upon oxidation with potassium permanganate it is converted into dimethoxybenzoic acid (veratric acid) which melts at 179 to 180° .²⁾ This same acid is likewise obtained upon the oxidation of methylisoeugenol. Both compounds, as also the methyleugenol nitrite,³⁾ m. p. 125 , can be utilized for the identification of methyleugenol.



When eugenol is heated with an excess of solid potassa,⁴⁾ or in amyl alcoholic solution,⁵⁾ or when eugenol potassium is heated to about 200° ⁶⁾ with exclusion of air, it is converted into the isomeric isoeugenol. This is also found in ylang-ylang oil and in oil of nutmeg. The following constants have been recorded:

B. p. 261° (not corr.);⁷⁾ $d_{15} 1.09$; $n_D 1.5680$;⁸⁾

B. p. 111 to 112° (3.5 mm.); $d_{15} 1.087$ to 1.091 ; $n_{D20} 1.570$ to 1.576 ; soluble in 5 to 6 vols. of 50 p. c. alcohol.⁹⁾

In a freezing mixture eugenol congeals to a mass of radiating needles which liquify at room temperature.¹⁰⁾

¹⁾ Wassermann, Jahresber. d. Chem. 1879, 520; Bertram and Gildemeister, Journ. f. prakt. Chem. II, 39 (1889), 354.

²⁾ Comp. also Wallach and Rheindorff, Liebig's Annalen 271 (1892), 306.

³⁾ Wallach, Liebig's Annalen 271 (1892), 307.

⁴⁾ Einhorn and Frey, Berl. Berichte 27 (1894), 2455.

⁵⁾ Tiemann, Berl. Berichte 24 (1891), 2870.

⁶⁾ D. R. P. 179948.

⁷⁾ Tiemann, Berl. Berichte 24 (1891), 2872.

⁸⁾ Eykman, Berl. Berichte 23 (1890), 862.

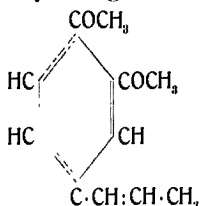
⁹⁾ Observations made in the Laboratory of Schimmel & Co.

¹⁰⁾ Tiemann, Berl. Berichte 24 (1891), 2872.

Upon oxidation it yields vanillin, in the manufacture of which it is largely used.

For its identification the following compounds may be employed: monobromisoeugenol dibromide, m. p. 138 to 139°; the acetyl derivative, m. p. 79 to 80°; the benzoyl derivative, m. p. 103 to 104°; and the diphenylurethane, m. p. 112 to 113°. In alcoholic solution isoeugenol produces an olive-green color with ferric chloride, whereas eugenol produces a blue color.

Methylisoeugenol.

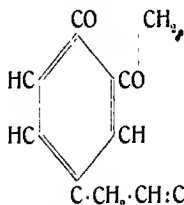


Thus far methylisoeugenol has been found only in the oil from *Asarum arifolium*. Artificially it is obtained by the methylation of isoeugenol and by the inversion of methyleugenol. The following properties have been recorded:

B. p. 263°;¹⁾ $d_{4,15} 1.064$; $n_D 1.5720$.²⁾

It yields a characteristic dibromide, m. p. 101 to 102°, and can be oxidized to veratric acid.

Safrol.



Safrol, $C_{10}H_{10}O_2$, is the principal constituent of oil of sassafras. It is also contained in appreciable amount in camphor oil from

¹⁾ Ciamician and Silber, Berl. Berichte 23 (1890), 1165.

²⁾ Eykman, Berl. Berichte 23 (1890), 862.

which it is obtained technologically. In addition it has been found in the oils of *Asarum arifolium*, *A. Blumei*, American wormseed oil, Japanese staranise oil, in the common staranise oil (traces), in the oils of apopin, ylang-ylang (?), nutmeg, cinnamon leaves, cinnamon root, in the oil from the bark of *Cinnamomum Mercadoi*, in pichurimbean oil (?), in California laurel oil, and in massoy bark oil. Safrol is the methylene ether of *m*-allylpyrocatechin.

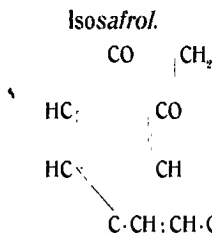
It is a colorless or slightly yellowish, optically inactive liquid, which upon cooling congeals to a crystalline mass, and possesses the following additional properties:

Congealing point about $+11^{\circ}$; b. p. 91° (4 mm.), 233° (759 mm.); $d_{15} 1.105$ to 1.107 ; $n_{D20} 1.536$ to 1.540 .¹⁾

Eykman²⁾ found: M. p. $+8^{\circ}$; b. p. 229 to 231° (uncorr.); $d_{15} 1.0960$; $d_{12} 1.110$; $n_D 1.5420$.

Subjected to careful oxidation with potassium permanganate, it yields first of all a glycol (m. p. 82 to 83°), which upon further oxidation yields α -homopiperonylic acid. $C_8H_8 \cdot (OOCH_2) \cdot CH_2COOH$ (m. p. 127 to 128°). When oxidized with chromic acid mixture, piperonal (heliotropin), m. p. 37° , and piperonylic acid, $C_8H_8 \cdot (OOCH_2) \cdot COOH$ (m. p. 228°) result.

When reduced in alcoholic solution with sodium, or with nickel in a current of hydrogen, safrol as well as *isosaflrol* yield the dihydro-derivative $C_{10}H_{12}O_2$ (b. p. 228°) and *m*-propylphenol (b. p. 228°).³⁾



When boiled with alcoholic potassa, safrol is changed to *isosaflrol*.

¹⁾ Observations made in the laboratory of Schimmel & Co.

²⁾ Recueil des trav. chim. des P.-B. 4 (1885), 32; Berl. Berichte 23 (1890), 862.

³⁾ Henrard, Chem. Weekblad 4 (1907), 630; Chem. Zentralbl. 1907, II. 1512.

For this compound, which possibly occurs in ylang-ylang oil, the following constants have been determined:

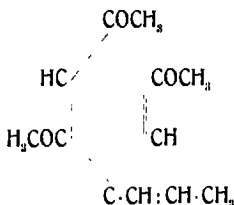
d_{15}° 1.124 to 1.129; $n_{D,20}^{\circ}$ 1.580.¹⁾

B. p. 253 to 254°; $d_{11.5}^{\circ}$ 1.126.²⁾

With an excess of bromine, *isosafral* yields a pentabromide, m. p. 196.5 to 197°.³⁾ Oxidized with chromic acid, it yields piperonal (heliotropin).

In commercial *isosafral*, Hoering and Baum⁴⁾ have demonstrated the presence of two geometric isomers, which they designated α - and β -*isosafral* and of which the latter predominates by far. They are distinguishable only by their odor and their physical constants. Those of α -*isosafral* lie between those of *safrol* and β -*isosafral*. Chemically no difference could be observed between the two *isocompounds*.

Asarone.



Asarone (4-propenyl-1,2,5-trimethoxybenzene), $\text{C}_{12}\text{H}_{16}\text{O}_3$, is a constituent of *Asarum* oil. It has been found in the oils of *calamus*, *matico* and *Asarum arilolium*. If present in larger amounts, it separates upon prolonged standing. Asarone has likewise been obtained synthetically.

In the pure state asarone is devoid of odor and taste and is further characterized by the following properties:

M. p. 61°;⁵⁾ d_{11}° 1.091; n_D^{20} 1.5719.⁶⁾

¹⁾ Observation made in the laboratory of Schimmel & Co.

²⁾ Eykman, Berl. Berichte 23 (1890), 859.

³⁾ Hoering, Berl. Berichte 34 (1905), 3466; 40 (1907), 1101.

⁴⁾ Berl. Berichte 42 (1909), 3076.

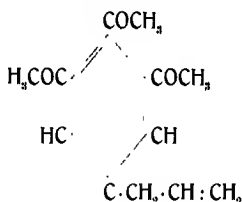
⁵⁾ Gattermann and Eggers, Berl. Berichte 32 (1899), 290.

⁶⁾ Eykman, *ibidem* 23 (1890), 862.

Upon bromination it yields the well crystallizable dibromide, $C_{12}H_{10}Br_2O_3$, m. p. 86° . When treated with sodium methylate in the cold, this in turn yields the crystalline $C_6H_2(OCH_3)_3 \cdot CH \cdot (OCH_3) \cdot CHBrCH_3$, which melts at 77.5° .

Oxidized with chromic acid, asarone yields asaryl aldehyde $C_{10}H_{12}O$, m. p. 114° . Together with asaronic acid [trimethoxybenzoic acid, $C_6H_2(OCH_3)_3 \cdot COOH$, m. p. 144°], this is also formed when asarone is oxidized with permanganate.

Elemicin.



Elemicin (4-allyl-1,2,6-trimethoxy benzene), $C_{12}H_{16}O_4$, constitutes the principal constituent of Manila elemi oil, in which it was discovered by Semmler¹⁾ who also gave it its name. It is found in fraction 277 to 280° of elemi oil.²⁾ In order to isolate elemicin, the fraction in question is boiled for half an hour with formic acid. As Semmler has demonstrated by experiments made on anethol and safrol, allyl compounds remain unchanged, whereas propenyl compounds are destroyed. Elemicin purified in this manner possessed the following properties:

B. p. 144 to 147° ; $d_{20} 1.063$; $n_D 1.52848$.

When oxidized in acetone solution with potassium permanganate trimethylgallic acid, $C_{10}H_{12}O_5$, m. p. 169° ; b. p. 225 to 227° , results.

When heated with sodium or with alcoholic potassa, *iso*-elemicin, an isomer of position to asarone, results. *Isoelemicin*

¹⁾ Berl. Berichte 41 (1908), 1768, 1918, 2183, 2556.

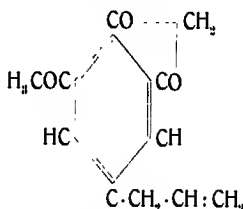
²⁾ Report of Schimmel & Co. October 1890, 29; April 1907, 41; October 1908, 51.

is 4-propenyl-1,2,6-trimethoxy benzene and is characterized by the following constants:

B. p. 153 to 156° (10 mm.); d_{20}° 1.073; n_D 1.54679.

Isoelemicin is characterized chemically by its dibromide, m. p. 88 to 89°. Like *clemicin*, it yields trimethylgallic acid upon oxidation with permanganate.

Myristicin.

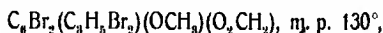


Thus far *myristicin* (4-allyl-6-methoxy-1,2-methylenedihydroxy benzene),¹⁾ $C_{11}H_{12}O_3$, has been found only in the oils of nutmeg and mace, also in French parsley oil. It is characterized by the following constants:

B. p. 171 to 173° (40 mm.); $d_{20}^{20^{\circ}}$ 1.1437; $n_D^{20^{\circ}}$ 1.54032; $n_D^{14.6^{\circ}}$ 1.52927;²⁾

B. p. 149.5° (15 mm.); d_{10}° 1.1425.³⁾

Even in a freezing mixture *myristicin* does not congeal. With bromine it yields dibrommyristicindibromide,



upon oxidation *myristicin* aldehyde and *myristicin* acid (see below).

When boiled with alcoholic potassa, or when treated with sodium, the allyl group is rearranged to the propenyl group

¹⁾ This is not to be confounded with the "myristicin" of John and Mulder, a stearoptene that occasionally crystallizes out of old oils and which consists of *myristicin* acid as shown by Flückiger [Pharmaceutical Journ. III 5 (1874), 136].

²⁾ Power and Salway, Journ. chem. Soc. 81 (1907), 2054.

³⁾ Thoms, Berl. Berichte 36 (1903), 3447.

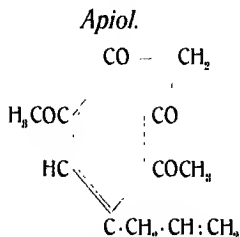
and the myristicin thereby changed to solid *isomyristicin* for which Power and Salway¹⁾ record the following constants:

M. p. 44°; b. p. 166° (18 mm.); $n_{D,15.5}^{20}$ 1.56551.¹⁾

Characteristic derivatives are the dibromide, m. p. 109°, and the dibrom/*isomyristicin* dibromide, m. p. 156°. Like myristicin, *isomyristicin* yields myristicin aldehyde, m. p. 130° and myristicin acid, m. p. 210°, upon oxidation with permanganate.

With nitrous acid both phenol ethers yield addition products from which a series of derivatives can be obtained.

The isomeric *apiols* $C_{12}H_{11}O_4 \cdot (O_2CH_2) \cdot (OCH_3)_2$ are derivatives of an unsaturated, tetratomic phenol. With reference to their occurrence they are designated *apiol*, *dillapiol*, also *allyltetramethoxy benzene*.



Apiol (4-allyl-3,6-dimethoxy-1,2-methylenedihydroxy benzene), $C_{12}H_{11}O_4$, is a constituent of parsley seed oil and of Venezuelan camphorwood oil and matiao oil from which it congeals upon cooling. *Apiol* has been examined more particularly by v. Gerichten,²⁾ Ginsberg,³⁾ Ciamician and Silber,⁴⁾ and Thoms.⁵⁾ The complicated constitution of this substance was almost completely revealed by Ciamician and Silber, but the final questions involved in establishing the above structural formula were settled by Thoms.

¹⁾ Power and Salway, Journ. chem. Soc. 91 (1907), 2055.

²⁾ Berl. Berichte 9 (1876), 258, 1477.

³⁾ *Ibidem* 21 (1888), 1192, 2514; 22 (1890), 323.

⁴⁾ *Ibidem* 21 (1888), 913, 1621; 22 (1889), 2481; 23 (1890), 2283.

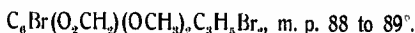
⁵⁾ *Ibidem* 36 (1903), 1714.

Apiol crystallizes in long colorless needles which possess a faint parsley odor and is characterized by the following constants:

M. p. 30° ; b. p. 294° (ord. pressure), 179° (33 to 34 mm.);¹⁾
 $d_{11^{\circ}}$ 1,176; n_D 1,5380.²⁾

B. p. 296 to 299° (755 mm., mercury entirely in the vapor);
 $d_{15^{\circ}}$ 1,1788 (supercooled).³⁾

Apiol is almost insoluble in water, soluble in alcohol, ether and the fatty oils. With bromine it combines to form tribromapiol,

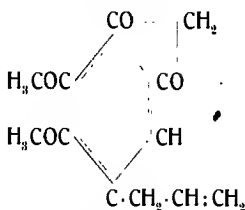


Oxidation converts it into apiol aldehyde and apiolic acid (see below).

Isoapiol, which results from the action of alcoholic potassa on apiol, crystallizes in monoclinic crystals which melt at 55 to 56° . Three bromine derivatives are known, a monobromide, m. p. 51° , a dibromide, m. p. 75° , and a tribromide, m. p. 120° .

Like apiol, *isoapiol* yields, upon oxidation with potassium permanganate, apiol aldehyde, $C_{10}H_{10}O_4$, m. p. 102° , and apiolic acid, $C_{10}H_{10}O_6$, m. p. 175° . Both phenol ethers also react with nitrous acid.

Dillapiol.



Dillapiol occurs in matico oil, in East Indian, Japanese, and Spanish dill oils, also in the oil of *Crithmum maritimum*. It is a viscid, oily liquid, which boils at 285° under ordinary pressure

¹⁾ Ciamician and Silber, Berl. Berichte 21 (1888), 1622.

²⁾ Eykman, *ibidem* 23 (1890), 862.

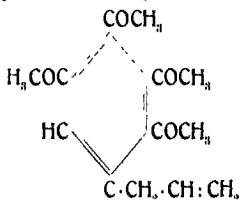
³⁾ Observations made in the laboratory of Schimmel & Co.

and at 162° under a pressure of 11 mm.¹⁾ Its constitution finds expression in the formula given above, the correctness of which has been established by Thoms.²⁾

When acted upon with an excess of bromine, dillapiol yields a substance $C_{12}H_{18}Br_2O_4$, which crystallizes in colorless prisms, melts at 110° , and which is the dibromide of monobromapiol.³⁾

Dillisoapiol, which is obtained by inversion, is solid, and can be obtained in monoclinic crystals that melt at 44° . Its boiling point is 296° . The melting point of the trihromide is 115° . When oxidized with alkaline permanganate solution, it yields dillapiol aldehyde, $C_{10}H_{10}O_6$, m. p. 75° , and dillapiolic acid, $C_{10}H_{10}O_6$, m. p. 151 to 152° . Whether dillisoapiol occurs in nature or not has not yet been ascertained.

Allyltetramethoxybenzene.



From a French oil of parsley Thoms⁴⁾ isolated a substance $C_{18}H_{18}O_4$, which he recognized as a phenol ether characterized by the above formula, and for which he records the following constants:

M. p. 25° ; d_{25} , 1.087; n_{D25} , 1.51462.

When oxidized with potassium permanganate, a good yield of tetramethoxy benzoic acid, $C_6H(OCH_3)_4COOH$ results, which crystallizes in long needles and melts at 87° .⁵⁾

In conclusion, several compounds may here be mentioned that are ketones as well as phenols. They are diosphenol and phloracetophenone dimethyl ether.

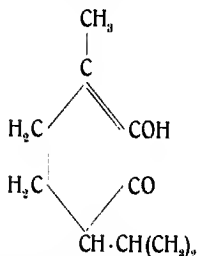
¹⁾ Ciamician and Silber, Berl. Berichte 29 (1896), 1800.

²⁾ Arch. der Pharm. 242 (1904), 344.

³⁾ Ciamician and Silber, loc. cit.

⁴⁾ Berl. Berichte 41 (1908), 2761.

⁵⁾ Bignami and Testoni, Gazz. chim. ital. 30 (1900), I. 240; Report of Schimmel & Co. October 1900, 48.

Diosphenol.

Diosphenol (buchu camphor), $\text{C}_{10}\text{H}_{16}\text{O}_2$, is a constituent of the oil of buchu leaves, in which it was first found by Flückiger.¹⁾ Since then it has been subjected to investigation repeatedly. Its chemical constitution was revealed by Semmler and Mc Kenzie,²⁾ who regard it as a cyclic reduced ketophenol of the above formula.

The diosphenol content of buchu oils varies with their botanical source. From some oils it separates as a crystalline mass upon standing at ordinary temperature, whereas other oils contain but little of this phenol. It is obtained from the oils either by freezing out, or by shaking out with dilute caustic alkali. If the latter method be followed, it should be remembered that a part of the diosphenol is removed when the alkaline solution is shaken out with ether.

Synthetically diosphenol is obtained by the oxidation of oxy-methylene-menthone, $\text{C}_{11}\text{H}_{18}\text{O}_2$. A diketone $\text{C}_{10}\text{H}_{16}\text{O}_2$ results which is inverted to diosphenol by means of acids or alkalis.³⁾

Diosphenol has a peculiar minty odor, is optically inactive, and crystallizes in monoclinic crystals that melt at 83° . It boils at 109 to 110° under 10 mm. pressure and with partial decomposition at 232° under atmospheric pressure. With ferric chloride it produces a dark green color.

With acetic acid anhydride and benzoylchloride, diosphenol yields the respective esters, with carbanil a phenylurethane melting at 41° . On account of the neighboring hydroxy group, the ketone group possess but little capacity for reaction. However, an oxime is known, which melts at 156° according to Kondakow and Bjalobrzieski,⁴⁾

¹⁾ Pharmaceutical Journ. III. 11 (1880), 174, 219.

²⁾ Berl. Berichte 30 (1906), 1158.

³⁾ Semmler and Mc Kenzie, *ibidem* 1169.

⁴⁾ Journ. f. prakt. Chem. II. 54 (1896), 437.

but Semmler and Mc Kenzie (*loc. cit.*) record the melting point as 125° . When reduced in alkaline solution with sodium amalgam a diol alcohol, $C_{10}H_{18}O_2$,¹⁾ results which melts at 159° . Reduction with sodium and alcohol yields *i*-menthol and a glycol $C_{10}H_{20}O_2$. Upon oxidation with potassium permanganate, the latter yields α -isopropyl- α' -methyladipinic acid, which melts at 104° .²⁾

Characteristic for diosphenol is its ready oxidation which property explains its capacity to reduce Fehling's solution, also ammoniacal silver solution.

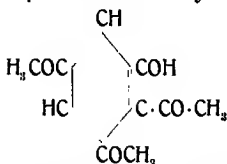
Upon oxidation with ozone Semmler and Mc Kenzie (*loc. cit.*) obtained α -isopropyl- γ -acetyl-*n*-butyric acid, m. p. 41° , whereas with potassium permanganate they obtained a ketoacid, $C_{10}H_{14}O_4$ which melts at 104 to 105° and yields an oxime melting at 182° . As an intermediate product an acid $C_{10}H_{16}O_4$ is formed from which the keto acid results by splitting off a molecule of water.

When diosphenol is heated with concentrated hydrochloric acid in a sealed tube to 150 to 180° , thymol, together with little carvacrol, results quantitatively.

When heated with alcoholic potassa in a sealed tube to 150 to 160° , it yields an alcohol acid $C_{10}H_{18}O_3$, which can readily be recrystallized from water in needles that melt at 94° .

Diosphenol is readily recognized by its properties. For its identification its behavior toward Fehling's solution and ammoniacal silver solution can be utilized. Of its derivatives the phenylurethane and the alcohol acid mentioned may also be used.

Phloracetophenone dimethyl ether.



Brief mention may be accorded to the phloracetophenone dimethyl ether, which was recently found by Jonas³⁾ in the oil of

¹⁾ Shimoyama, Arch. der Pharm. 226 (1888), 413.

²⁾ Kondakow and Bachtshiew, Journ. f. prakt. Chem. II. 63 (1901), 61; Semmler and Mc Kenzie, Berl. Berichte 39 (1906), 1162.

³⁾ Report of Schimmel & Co. April 1909, 150.

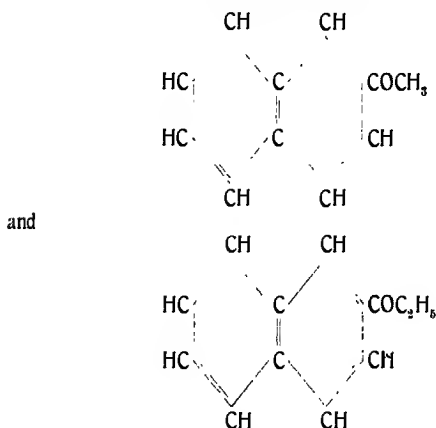
Blumea balsamifera. This compound can be shaken out of the oil with the aid of caustic soda solution. From this alkaline solution, acids precipitate it as a solid, yellowish substance which after repeated recrystallization from benzene or light petroleum ether is obtained colorless and melts at 82 to 83°.

Phloracetophenone dimethyl ether had previously been obtained synthetically by Friedländer and Schnell¹⁾ and was later made the subject of careful study by v. Kostanecki and Tambor.²⁾

Of its derivatives the oxime melts at 108 to 110°, the acetyl compound at 106 to 107°, the methyl ether at 103°, and a yellow crystalline monobromide at 187°.

Condensed with benzaldehyde it yields 2-hydroxy-4, 6-dimethoxychalcone (m. p. 91 to 92°).

β-Naphthol ether.



The methyl and ethyl ethers of β-naphthol are both used extensively for perfuming cheaper grades of soap. In commerce these ethers are known as nerolin. The methyl ether is sometimes differentiated as nerolin "old" or "jara-jara", the ethyl ether as nerolin "new" or "bromelia". Neither of these ethers have

¹⁾ Berl. Berichte 30 (1897), 2152.

²⁾ *Ibidem* 32 (1899), 2262.

been found in nature thus far. They are prepared artificially by digesting for several hours β -naphtholpotassium with the molecular amounts of the respective alkyl halides in methyl or ethyl alcoholic solution.¹⁾ According to another method,²⁾ one part of β -naphthol, three parts of methyl or ethyl alcohol and one part of hydrochloric acid are heated in an autoclave to 150°. Simpler, however, is the method of Henriques, originally used for the preparation of α -naphthol ethers, but which, according to Gattermann,³⁾ is likewise well suited to the preparation of β -naphthol ethers. It consists in heating β -naphthol with the respective alcohol and sulphuric acid to 125 to 140° using a reflux condenser. The methyl ether results better when a slight pressure is employed.

Both ethers consist of colorless crystalline laminæ, which are rather difficultly soluble in methyl and ethyl alcohol, but readily soluble in other organic solvents. The odor of both ethers is strong and persistent, however, that of the ethyl ether is more delicate than that of the methyl ether. In great dilution their odor resembles that of orange blossom oil, for which they are a cheap, though not perfect, substitute. The odor of the ethyl ether is also compared with that of pine apple, though the comparison does not seem fully justified. It is possibly due to this analogy that the name *Bromelia* may be traced.

The following constants for β -naphthol methyl ether are recorded in chemical literature:

M. p. 72°;⁴⁾ m. p. 70°, b. p. 274°;⁵⁾

and for β -naphthol ethyl ether:

M. p. 37°;⁶⁾ b. p. 274 to 275°;⁷⁾ 282° (corr.); d_{40° 1.0547, d_{80° 1.501.⁸⁾

¹⁾ Schaeffer, Liebig's Annalen 152 (1869), 286.

²⁾ Liebermann and Hagen, Berl. Berichte 15 (1882), 1428.

³⁾ Liebig's Annalen 244 (1888), 72.

⁴⁾ Stadel, Liebig's Annalen 217 (1883), 43.

⁵⁾ Marchetti, Gazz. chim. ital. 9 (1879), 544; Jahresber. d. Chem. 1879, 543.

⁶⁾ Orndorff and Kortright, Americ. chem. Journ. 13 (1891), 162.

⁷⁾ Liebermann and Hagen, Berl. Berichte 15 (1882), 1428.

⁸⁾ Perkin, Journ. chem. Soc. 69 (1896), 1190.

ACIDS.

The aqueous distillate obtained as a byproduct in the preparation of volatile oils occasionally contains free fatty acids such as acetic, propionic, butyric or valeric acids. Like the methyl and ethyl alcohol obtained in like manner, these acids are in all probability decomposition products of esters contained in the parts of plants subjected to distillation. In as much as the lower fatty acids remain dissolved in the aqueous distillates they are readily overlooked. In certain cases the amounts are not inappreciable. Thus e. g. in a distillation of 40 kg. of seeds of *Heracleum giganteum* 120 g. of oil were obtained and 30 g. of acetic acid were separated from the aqueous distillate.¹⁾

Although as a rule the percentage of acid in an oil is relatively low, there are a few oils consisting principally of acids. By way of example, orris oil contains 85 p. c. of myristic acid, the oil from *Polygonum Persicaria* consists largely of a mixture of volatile fatty acids,²⁾ in Mexican valerian oil 89 p. c. of valeric acid have been found,³⁾ and the oil of *Morinda citrifolia* contains as much as 90 p. c. of acid.⁴⁾

In the compilation of acids which follows, no differentiation is made between free acids and combined acids. This failure is due to two reasons. First, accurate statements are mostly wanting on this point. And, secondly, it may well be assumed that in most instances the presence of free acid is due to decomposition during the process of distillation. Upon saponification of the oils, the acids are obtained in the form of their salts.

Formic acid, $H\cdot COOH$, has been found in turpentine oil (?), in thuja oil, the oils of Ceylon cardamoms, ylang-ylang, nutmeg, California laurel, in the oil from the fruits of *Pittosporum undulatum*, in the oils of myrrh and carrot, in the oil from the

¹⁾ Zincke, Liebig's Annalen 152 (1869), 21.

²⁾ Horst, Chem. Ztg. 25 (1901), 1055.

³⁾ Report of Schimmel & Co. April 1897, 44.

⁴⁾ van Romburgh, Koninklijke Akademie van Wetenschappen te Amsterdam 1909, 17; Report of Schimmel & Co. October 1909, 78.

wood of *Goupia tomentosa*, in the oils of American pennyroyal, valerian, *Achillea nobilis*, and in the aqueous distillates of *Pinus Sabiniana*, *Eucalyptus Globulus*, *Æthusa Cynapium*, *Micromeria Chamissonis*, *Lippia scaberrima* and *Arnica montana*.

Formic acid is characterized by its great capacity for reduction. For purposes of identification, its solution, neutralized with alkali, is heated with mercuric chloride, where upon a precipitate of mercurous chloride and mercury results. The silver salt results upon the addition of silver nitrate to a solution of the formate. Upon heating it is decomposed and thus distinguished from acetic acid.

Acetic acid, $\text{CH}_3\cdot\text{COOH}$, is the most common of the acids found in volatile oils. An enumeration of its occurrences would include almost all of the volatile oils. Its esters are mostly characterized by an especially agreeable odor. Hence they find manifold application in perfumery. This is especially true of linalyl and geranyl acetates. A few oils consist largely of acetic esters, e. g. the oils of lavender, bergamot, petitgrain, Siberian pine needle oil, &c.

For the purpose of identifying acetic acid, silver nitrate is added to the neutralized aqueous solution. The silver salt thus obtained is analysed. As a rule this method is generally applicable for the identification of most fatty acids.

Of the remaining fatty acids, the following have been found in volatile oils:

Propionic acid, $\text{C}_2\text{H}_5\cdot\text{COOH}$, in the oils of chamomile, male fern (?), pastinaca and lavender.

n-Butyric acid, $\text{C}_4\text{H}_9\cdot\text{COOH}$, in the oils of male fern, *Polygonum Persicaria*, nutmeg, *Eucalyptus Globulus*, niaouli, *Æthusa Cynapium*, *Heracleum Sphondylium*, *H. giganteum*, lavender, valerian, American pennyroyal, and in the aqueous distillate of *Lippia scaberrima* and *Micromeria Chamissonis*.

Isobutyric acid has been found in laurel leaf oil, in the oil of Ceylon cinnamon (?), carrot oil (?), Cretan origanum oil (?), arnica root oil and Roman chamomile oil.

Isovaleric acid (isopropyl acetic acid), $C_4H_9 \cdot COOH$, has been found, in the oils of male fern (?), cypress, citronella, laurel leaves, in the oil from the fruits of *Pittosporum undulatum*, in the oils of geranium (?), niaouli, *Eucalyptus goniocalyx*, *E. paludosa*, *E. saligna*, and senega root, in the oil from the wood of *Goupia tomentosa*, and in the oils of lavender (?), American peppermint, valerian, Mexican valerian, kcsso root and wormwood.

Methyl ethyl acetic acid in the oils of champaca, angelica root and coffee.

Caproic acid, $C_6H_{11} \cdot COOH$, in the oils of male fern (?), *Juniperus phoenicea*, lemongrass, palmarosa, laurel leaves (?), *Heracleum Sphondylium*, pastinaca, in the oil from the wood of *Goupia tomentosa*, and in the oils of lavender and of the fruits of *Morinda citrifolia*.

Isoheptoic acid, $C_8H_{15} \cdot COOH$, in American pennyroyal oil.

Caprylic acid, $C_8H_{15} \cdot COOH$, in the oils of wormseed (?), nutmeg, camphor, sweet orange, American pennyroyal, in the oil from the fruits of *Morinda citrifolia* and the oil of *Artemisia Herba-alba*.

Caprinic acid, $C_9H_{17} \cdot COOH$, crystallizes in needles melting at 31° and has been found in lemongrass oil, kobuschi oil, heracleum oil, American pennyroyal oil, chamomile oil, and in the oil of *Artemisia Herba-alba*.

Lauric acid, $C_{11}H_{23} \cdot COOH$, crystallizes as needles which melt at 43.6° . It occurs in the oils from the laurel berry, the pichurim bean, *Psoralea bituminosa* (?), the wood of *Goupia tomentosa* and *Heracleum*.

Myristic acid, $C_{13}H_{27} \cdot COOH$, crystallizes in laminæ that melt at 53.8° . It occurs in the oils of nutmeg, *Blumea balsamifera* and orris root.

Palmitic acid, $C_{15}H_{31} \cdot COOH$, crystallizes as scales that melt at 62° . It occurs in the oils of Canada snakeroot, Japanese star anise, myrrh, cascarilla, ambrette seeds (?), the fruit of

Pittosporum undulatum, pimenta, the seeds of *Monodora grandiflora*, celery seed, parsley seed, carrot, *Micromeria Chamissonis*, the stems and leaves of *Tagetes patula*, carline thistle, arnica flowers, wormwood, and *Blumea balsamifera* (?).

Stearic acid, $C_{17}H_{35}\cdot COOH$, crystallizes in laminæ that melt at 69.2° and occurs in cascarilla oil.

Unsaturated acids have been found in only a few instances.

Methacrylic acid, $CH_2\cdot C(CH_3)COOH$, crystallizes in long prisms and melts at 15 to 16° , b. p. 160.5° . It probably occurs in Roman chamomile oil.

Angelic acid, $CH_3\cdot CH\cdot C(CH_3)COOH$, melts at 45 to 45.5° and boils at 185° . It has been found in the aqueous distillate of the oils of angelica root and Roman chamomile.

Tiglic acid, $CH_3\cdot CH\cdot C(CH_3)COOH$, melts at 64.5° , boils at 198.5° and occurs in geranium oil.

Oleic acid, $C_{18}H_{33}\cdot CH\cdot CH(CH_3)COOH$, crystallizes in needles that melt at 14° and boil at 223° (10 mm.). It occurs in orris oil and kobusechi oil.

Of *hydroxy acids* the following have been identified:

Hydroxymyristic acid, $C_{11}H_{21}O_3$, crystallizes in pearly laminæ that melt at 51° . It occurs in sabadilla seed oil and in angelica seed oil.

Hydroxypentadecylic acid, $C_{15}H_{31}O_3$, crystallizes in needles that melt at 84° . It occurs in angelica root oil and possibly in Japanese angelica oil.

A *dibasic acid* has been observed but once as a natural constituent of a volatile oil, viz.

Succinic acid, $COOH\cdot CH_2\cdot CH_2\cdot COOH$, in the oil from the wood of *Goupia tomentosa*.

Of *aliphatic acids* there remain to be mentioned

Citronellic acid, $C_9H_{17}\cdot COOH$, which boils at 257° or 143.5° (5 mm.). It occurs in the oil of *Barosma pulchellum*.

Teresantalic acid, a reduced cyclic acid, $C_{10}H_{14}O_2$, which melts at 157° , $[\alpha]_D - 70^\circ 24'$ (in 25 p. c. solution) occurs in sandal wood.

Of *aromatic acids* the following should be mentioned:

Benzoic acid, $C_6H_5 \cdot COOH$, crystallizes in shiny laminæ that melt at $121,4^\circ$, and boil at 249° (760 mm.). It occurs in the oils of vetiver, tuberose, hyacinth, champaca, ylang-ylang, cinnamon leaves, wild cherry bark, neroli, tolubalsam and cloves.

Phenylacetic acid, $C_6H_5 \cdot CH_2 \cdot COOH$, crystallizes in thin laminæ that melt at $76,5^\circ$ and boil at $265,5^\circ$. It occurs in neroli oil.

Cinnamic acid, $C_6H_5 \cdot CH:CH \cdot COOH$, melts at 133° and boils at 300° . It occurs in the oils of *Alpinia*, *Kæmpferia*, *xanthorrhæa* resin, storax, American storax, cassia and wartara.

Salicylic acid, $C_6H_4 \cdot OH \cdot COOH$, m. p. 155 to 157° , occurs widely distributed as methyl ester (see p. 504). In addition it has been found in the oils of spicewood, ylang-ylang, *Pittosporum undulatum*, and American pennyroyal.

Anisic acid, *p*-methoxybenzoic acid, $C_6H_4 \cdot OCH_3 \cdot COOH$, melts at 184° , occurs in the Tahiti vanilla. It is also found in all oils which, like anise oil, contain much anethol, from which it results upon oxidation.

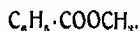
Veratric acid, $(CH_3O)_2 \cdot C_6H_3 \cdot COOH + H_2O$, melts between $179,5$ and 181° , and has been found in the oil of saba-dilla seed.

Methyl-p-cumaric acid, *p*-methoxycinnamic acid, $CH_3O \cdot C_6H_4 \cdot CH:CH \cdot COOH$, melts at 171° and occurs in *Kæmpferia* oil.

ESTERS.

Esters occur in most volatile oils and are frequently of essential import so far as the fragrance of these oils is concerned. On account of their mostly pleasant odor they play an important role in perfumery. As illustrations of oils rich in esters, the oils of bergamot, lavender, geranium, Siberian pine needle and Roman chamomile may be mentioned. It rarely happens that an oil consists almost exclusively of esters. Such is the case with the distillates of *Gaultheria procumbens* and *Betula lenta*, which consist to the extent of about 99 p. c. of methyl salicylate, and which are commonly known as wintergreen oil. With the exception of those esters which are solid at ordinary temperature and hence can be readily isolated, the identification of esters is not an easy matter. Characteristic derivatives, such as can be prepared of alcohols, ketones and hydrocarbons, are known only in exceptional cases. Hence one is dependant on fractional distillation and the characterization of the saponification products. To this difficulty is added the circumstance that the boiling points of esters of different composition are close to each other. As a result separation by fractionation is rendered impossible. A further difficulty arises from the decomposition of many esters when distilled under ordinary pressure. Some decompose even when distilled under diminished pressure.

As a rule, esters can be readily obtained synthetically. A common method consists in passing hydrogen chloride into a mixture of the components, which mixture is some times diluted with a suitable solvent. In many instances, however, this method cannot be applied because of the susceptibility of some of the acids and alcohols toward hydrogen chloride. In such cases the ester can be obtained by the action of the alkyl iodide on the silver salt of the acid, or by the action of acid anhydrides or acid chlorides on alcohols. Not infrequently mere boiling of the alcohol with the acid anhydride suffices. Thus many alcohols can be converted quantitatively into their acetates by boiling them with acetic acid anhydride and some anhydrous sodium acetate.

Methyl benzoate.

The methyl ester of benzoic acid, also known as oil of Niobe, occurs in ylang-ylang oil and probably also in the oils of cloves and of tuberose. It is a colorless, optically inactive liquid, of a strong but pleasant odor.

B. p. $199,2^\circ$ (746,4 mm.); $d_{20} 1,1026$,¹⁾ $d_{15}^{15} 1,0942$.²⁾

In the laboratory of Schimmel & Co. the following constants have been observed:

$d_{15} 1,0935$ to $1,0955$; $n_{D20} 1,517$ to $1,418$; sol. in 4 vol. of 60 p. c. and in 1,5 vol. of 70 p. c. alcohol.

Characteristic for methyl benzoate is its crystalline derivative with phosphoric acid.³⁾ The benzoates of the homologous alcohols do not possess this property.

Methyl cinnamate.

The only oils in which this ester has been found are those from the rootstock and leaves of *Alpinia malaccensis* and from the seeds of wartara.

At ordinary temperature methyl benzoate is a solid possessing a peculiar, intensive odor, and characterized by the following properties:

M. p. $33,4^\circ$; b. p. 263° .⁴⁾

M. p. 36° ; h. p. $259,6^\circ$; $d_{20}^{20} 1,0415$.⁵⁾

For the methyl cinnamate from wartara oil, Schimmel & Co.⁶⁾ observed:

¹⁾ Kopp, Liebig's Annalen 94 (1855), 307, 309.

²⁾ Perkin, Journ. chem. Soc. 89 (1896), 1174.

³⁾ Ralkow, Chem. Ztg. 24 (1900), 368.

⁴⁾ Anschütz and Kinnicutt, Berl. Berichte 11 (1878), 1220.

⁵⁾ Weger, Liebig's Annalen 221 (1883), 74.

⁶⁾ Report of Schimmel & Co. April 1901, 59.

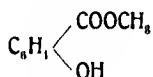
M. p. 36°; b. p. 256° (745 mm.);

and for technical preparations of their own manufacture:

M. p. 34 to 35°; d_{15}^{40} 1.0663; n_{D83} 1.56816; n_{D84} 1.56729; d_{15}^{30} 1.0712; n_{D86} 1.56816.

Methyl cinnamate is readily soluble in the ordinary organic solvents, likewise in olive oil and paraffin oil. Of 70 p. c. alcohol 2 vol. are requisite to effect solution.

Methyl salicylate.



Methyl salicylate (salicylic acid methyl ester, artificial oil of wintergreen) is one of the most important perfumes and is also highly esteemed on account of its antiseptic properties. It has been known for a long time, and, as has been demonstrated in the course of years, is very widely distributed in the vegetable kingdom. Neither is its occurrence restricted to a certain part of the plant, but is found in all organs from the root to the flower. It constitutes the bulk of the oils of gaultheria and sweet birch. It has also been found in the oils of tuberose (from pomade), ylang-ylang, beech seedlings, in Roman and French cassie flowers, rue, tea, cloves, *Viola tricolor*, likewise in the following plants:¹⁾ *Podocarpus chinensis*, *P. Nageia*, *Gnetum Gnemon* β *ovalilolium*, *Castanopsis javanica*, *C. j.* var., *C. Tungurrut*, *C. spec.*, *Quercus spec. div.*, *Q. bancana*, *Q. glandulifera*, *Q. Junghuhnii*, *Q. pseudomoluccana*, *Q. spicata*, *Q. Teysmannii*, *Cecropia Schiedeana*, *Cinocephalus ovatus*, *C. suaveolens*, *C. spec.*, *Urostigma acamptophyllum*, *Ficus elastica*, *F. Benjamina*, *F. B.* var. *crassinerve*, *F. annulata*, *F. geniculata*, *F. pilosa*, *F. p.* var. *chrysocannia*, *F. retusa* var. *nitida*, *F. xylophylla*, *Sloetia Sideroxylon*, *Streblus mauritanus*, *Gironniera subaequalis*, *Myristica intermedia*, *Lindera Benzoin*, *Parinarium*

¹⁾ Compare: van Romburgh, *Verslag van 's lands plantentuin te Buitenzorg* 1897, 37; 1898, 29; 1901, 58; Kremers and James, *Pharm. Review* 16 (1898), 100; Report of Schimmel & Co. Oct. 1899, 56; Tailleux, *Compt. rend.* 132 (1901), 1235.

spec.; *Photinia serrata*, *Rubus sundaicus*, *Spiræa Ulmaria*, *Acacia Intsia*, *A. pluricapitata*, *A. sarmentosa*, *A. tenerrima*, *Bauhinia pyrrhaneura*, *Cæsalpinia Bonducella*, *Guilandina* spec., *Mucuna gigantea*, *Erythroxylon Coca*, *E. bolivianum*, *Canarium* spec., *Garuga* spec., *Polygala Senega*, *P. S. var. latilolia*, *P. Baldwini*, *P. variabilis*, *P. javana*, *P. oleilera*, *P. serpyllacea*, *P. calcarea*, *P. vulgaris*, *Epirixanthes elongata*, *E. cylindrica*, *Adenocrepis javanica*, *Antidesma diandrum*, *Agyneia multillora*, *A. spec.*, *Baccaurea* spec., *Cyclostemon macrophyllus*, *Bridelia tomentosa*, *Elateriospermum Tokbrai*, *Cluytia oblongilolia*, *Leiocarpus arboreus*, *L. spec.*, *Pierardia dulcis*, *P. spec. div.*, *Phyllanthus zeylanicus*, *Rottlera dispar*, *Sphenodesme Wallichiana*, *Trewia* spec., *Mangilera* spec., *Semecarpus* spec., *Turpinia sphærocarpa*, *T. spec.*, *Capura alata*, *Harpullia imbricata*, *H. spec.*, *Meliosma pendula*, *Mischocarpus luscenscens*, *Elæocarpus resinosus*, *Wormia triquetra*, *Thea chinensis*, *T. cochinchinensis*, *Calpandria lanceolata*, *Hydnocarpus Wightiana*, *H. alpina*, *H. venenata*, *Scolopia Roxburghii*, *Taraktogenos Blumei*, *Alsodeia cymulosa*, *Viola tricolor*, *Homalium tomentosum*, *H. javanicum*, *Carallia symmetria*, *Meme-cylon* spec., *Nania vera*, *Barringtonia rubra*, *B. spicata*, *B. spec. div.*, *Monotropa Hypopithys*, *Gaultheria Iragrantissima*, *G. leucocarpa*, *Ardisia humilis*, *A. lurida*, *A. luliginosa*, *A. macrophylla*, *A. purpurea*, *A. reclinata*, *A. sanguinolenta*, *A. speciosa*, *A. spec.*, *Sideroxylon obovatum*, *Diospyros aurea*, *D. caulillora*, *D. acuminata*, *D. Gardneri*, *Maba* spec., *Symplocos* spec. div., *S. lasculata*, *Chionanthus elliptica*, *C. latilolia*, *C. montana*, *C. ramillora*, *C. spec.*, *Allamanda Hendersoni*, *Chilocarpus densillorus*, *C. denudatus*, *C. spec.*, *Melodinus lævigatus*, *M. orientalis*, *Landolphia Watsonii*, *Alstonia angustifolia*, *A. Hædti*, *A. macrophylla*, *A. villosa*, *A. spec.*, *Hunteria corymbosa*, *Rauwolfia spectabilis*, *Cryptolepis laxillora*, *Marsdenia tenacissima*, *Cordia asperima*, *Bignonia Chamberlaynii*, *B. exoleta*, *Tecoma mexicana*, *Hexacentris coccinea*, *Nyctocalos brunelsiællorus*, *Thunbergia grandiflora*, *Canthium palembanicum*, *C. spec.*, *Gardenia Fitzalani*, *G. Schœmannii*, *Nauclea lagilolia*, *N. polyccephala*, *N. spec.*, *Pavetta angustilolia*, *P. arborea*, *P. barbata*, *P. grandillora*, *P. g. var. lutea*, *P. g. var. aurantiaca*, *P. littorea*, *P. longillora*, *P. rosea*, *P. paludosa*, *P. longipes*, *P. spec.*,

Petunga variabilis, *P. spec.*, *Psychotria celastroides*, *P. robusta*, *P. undata*, *Wendlandia spec.*, *Anthocephalus Cadamba*, *Collea densiflora*, *C. lepidophloia*, *C. liberica*, *C. stenophylla*, *Grillithia acuminata*, *G. eucantha*, *Mussaenda Irondosa*, *M. olli-cinalis*, *M. rulinervia*, *Polyphragmon spec.*, *Randia densiflora*, *R. dumetorum*, *R. uliginosa*, *Sarcocephalus subditus*, *Scyphos-tachys colleoides*, *Viburnum sundaicum*, *Stiftia chrysantha* and *Vernonia arborea*.

As a rule, methyl salicylate does not occur as such in the vegetable kingdom, but in the form of a glucoside. Thus in the leaves of *Gaultheria procumbens* and in sweet birch bark it occurs as gaultherin from which it is set free by ferment action. Hence the yield of methyl salicylate from these sources is greatly increased if the material is moistened and set aside for several hours. In the case of many of the above mentioned plants the distillate from fresh material contains no methyl salicylate whatever.

As to the nature of the methyl salicylate-yielding glucosides little is as yet known. In addition to the gaultherin already mentioned primverin and primulaverin yield methyl salicylate. Both glucosides occur in the *Primulaceæ* and are hydrolysed by primverase, the accompanying ferment.¹⁾

Artificially methyl salicylate is obtained by heating methyl alcohol and salicylic acid in the presence of sulphuric acid. On a large scale this ester has been manufactured by Schimmel & Co. since 1886 and is placed upon the market as artificial oil of wintergreen.

Methyl salicylate is a colorless liquid, which is optically inactive and possesses an intense, peculiar odor. As to its other properties, the following data have been recorded:

B. p. 217° (730 mm.);²⁾

B. p. 223.7° (corr.); d_{20}^4 1.1969, d_{16}^4 1.1819;³⁾

M. p. — 8.3°;⁴⁾

B. p. 222.2° (corr.), d_4^{20} 1.1992, d_{15}^{20} 1.1890.⁵⁾

¹⁾ Goris and Mascré, Compt. rend. 149 (1909), 947.

²⁾ Schreiner, Liebig's Annalen 197 (1879), 17.

³⁾ Kopp, *Ibidem* 94 (1855), 301, 302.

⁴⁾ v. Schneider, Zeitschr. f. physik. Chem. 22 (1897), 233.

⁵⁾ Perkin, Journ. chem. Soc. 69 (1896), 1187.

In connection with technical products, Schimmel observed the following constants:

d_{16}^4 , 1,185 to 1,190; n_{D20}^4 , 1,536 to 1,538; soluble in 6 to 8 vol. of 70 p. c. alcohol.

Methyl salicylate dissolves in potassium hydroxide solution of medium concentration forming the readily soluble ester salt potassium methyl salicylate. From such a solution it can be recovered unchanged by means of dilute acids. Sodium hydroxide solution precipitates the difficultly soluble sodium methyl salicylate. When heated with an excess of alkali, both ester salts are saponified. From these saponified solutions, acid precipitates salicylic acid.

Characteristic for salicylates is the violet color produced by ferric chloride.

Ethyl acetate.



The presence of ethyl acetate (acetic ether) in volatile oils has not yet been demonstrated. However, an observation by Göppert¹⁾ is on record, according to which the flowers of *Magnolia fuscata*, more particularly the fallen petals, develop an odor closely resembling that of ethyl acetate. Hence this ester, though of technical and particularly of pharmaceutical importance, is of little interest to the perfumery chemist. Ethyl acetate is a colorless, neutral liquid possessing a refreshing odor. It boils at approximately 76° and at 15° has a specific gravity of 0,90 to 0,91. With the ordinary organic solvents it is miscible in all proportions. For many substances it acts as a good solvent. 18 p. of water dissolve 1 p. of acetic ether. On the other hand 28 p. of acetic ether dissolve 1 p. of water.

Ethyl benzoate.



Thus far ethyl benzoate has not been found in nature. Its odor resembles that of the methyl ester, but is somewhat milder. Its constants are:

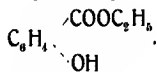
¹⁾ Liebig's Annalen 111 (1859), 127.

B. p. 211,2° (729 mm.); $d_{18^{\circ}}$ 1,0502;¹⁾ b. p. 212,9° (745,5 mm.).²⁾

In connection with technical preparations of their own manufacture, Schimmel & Co observed:

$d_{18^{\circ}}$ 1,0515 to 1,0523; $n_{D,20^{\circ}}$ 1,50501 to 1,50630; soluble in 7,5 vol. of 60 p. c. and in 2 vol. of 70 p. c. alcohol.

Ethyl salicylate.



Salicylic acid ethyl ester is of interest only in so far as it finds application in perfumery. In volatile oils it has not yet been found. It is a colorless liquid, the odor of which is more faint than that of wintergreen. Perkin³⁾ records the following properties:

B. p. 233,5 to 234,0° (corr.); $d_{18^{\circ}}$ 1,1372.

Schimmel & Co. found:

B. p. 234 to 235° (743 mm.), 91° (5 mm.); $d_{18^{\circ}}$ 1,1352; α_D -1 0°; $n_{D,20^{\circ}}$ 1,52338; soluble in 4 vol. of 80 p. c. alcohol.

When strongly cooled it can be made to congeal and then melts at -1,3°.⁴⁾

Ethyl cinnamate.



Cinnamic acid ethyl ester is one of the more rarely occurring constituents of volatile oils. Its occurrence is restricted to the oils of *kæmpferia* and *storax*. Artificially it is obtained by passing hydrogen chloride gas into the alcoholic solution of cinnamic acid. The ester is a liquid which has a pleasant odor, congeals at lower temperature, is optically inactive and possesses the following additional properties:

¹⁾ Linnemann, Liebig's Annalen 160 (1871), 208.

²⁾ Kopp, *Ibidem* 94 (1855), 309.

³⁾ Journ. chem. Soc. 69 (1896), 1176.

⁴⁾ v. Schneider, Zeitschr. f. physik. Chem. 19 (1896), 158.

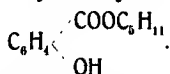
M. p. 12° ; ¹⁾ b. p. 271° ; ²⁾ d_0 , 1,0656, $d_{20.2^{\circ}}$ 1,0498; ³⁾

B. p. $195,5^{\circ}$ (103 mm.); $d_{15^{\circ}}$ 1,0546.⁴⁾

In connection with technical products Schimmel & Co. observed:

$d_{15^{\circ}}$ 1,053 to 1,055; $n_{D20^{\circ}}$ 1,559 to 1,561; soluble in 5 to 7 vol. of 70 p. c. alcohol.

Amyl salicylate.



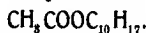
While not a constituent of volatile oils, salicylic acid amyl ester, also known as orchidée, trèfle or trefol, finds extensive application in perfumery and may, therefore, be mentioned. It is a colorless or yellowish liquid, the strongly aromatic odor of which reminds of some of the orchids. In connection with products of their own make Schimmel & Co. observed the following properties:

B. p. 276 to 277° (743 mm.), 151 to 152° (15 mm.); $d_{15^{\circ}}$ 1,049 to 1,055; α_D , slightly dextrogyrate, up to $+2^{\circ}$; $n_{D20^{\circ}}$ 1,505 to 1,507; soluble in about 3 vol. of 90 p. c. alcohol.

In as much as the ester is not readily saponifiable, it is necessary for a quantitative saponification to heat it with an excess of alkali for two hours on a water bath. Indeed, it is well to apply this precaution to other esters of salicylic acid.

In addition to its use as a perfume, amyl salicylate is also employed to fix the odor of finer perfumes. Therapeutically it has also been successfully employed as a remedy against rheumatism.⁵⁾

Linalyl acetate.



Linalyl acetate, the most valuable and characteristic constituent of the oils of bergamot and lavender, is rather widely

¹⁾ Wegener, Private communication by Friedländer, Liebig's Annalen 221 (1883), 75.

²⁾ Anschütz and Kinnicutt, Berl. Berichte 11 (1878), 1220.

³⁾ Kopp, Liebig's Annalen 96 (1855), 320.

⁴⁾ Perkin, Journ. chem. Soc. 69 (1896), 1228.

⁵⁾ According to Pharm. Zentralh. 43 (1902), 637.

distributed. In addition to the above mentioned two oils, it has been found in the oils of Canada snakeroot (?), ylang-ylang (?), sassafras leaves, the bark of *Cinnamomum pedatinervium*, petitgrain, lemon, neroli, the Italian limette, jasminc, muscatelle sage (?), the oil of the leaves of *Mentha citrata* and gardenia.

Since both linalool and linalyl acetate readily undergo change and decomposition, the artificial preparation of the ester is not readily accomplished. Thus the common method of acetylation yields but poor results since the linalool is partly decomposed, partly rearranged to terpineol, geraniol and nerol. According to Tiemann¹⁾ a pure linalyl acetate can be obtained by the interaction between sodium linalool and acetic acid anhydride.

Linalyl acetate is a colorless liquid with a pleasant odor reminding of bergamot. In accordance with the linalool employed, it deviates the ray of polarized light either to the right or left. In connection with a linalyl acetate prepared according to Tiemann's method, Hesse and Zeitschel²⁾ observed the following constants:

B. p. 96,5 to 97° (10 mm.), 115 to 116° (25 mm.), about 220° with decomposition (762 mm.); d_{15}° , 0,913; $[\alpha]_D$, -6° 35'; ester content 97,6 p. c.

Under the name of bergamiol, Schimmel & Co. introduce into the market a product that possesses approximately the following properties:

d_{15}° , 0,90 to 0,91; $n_{D,20}^{\circ}$, 1,451 to 1,454; soluble in 10 to 15 vol. of 60 p. c. and in 3 to 5 vol. of 70 p. c. alcohol.

Geranyl formate.



This ester, which has not yet been observed in nature, is formed even upon standing of a solution of geraniol in crystallized formic acid,³⁾ better still upon the addition of a small amount of a mineral acid.⁴⁾ According to Tiemann (*loc. cit.*) the ester

¹⁾ Berl. Berichte 31 (1898), 839.

²⁾ Journ. f. prakt. Chem. II. 64 (1901), 256.

³⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 907, footnote.

⁴⁾ Bertram, G. I. P. 80 711.

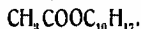
boils at 113 to 114° (15 mm.), according to Bertram at 104 to 105° (10 to 11 mm.).

In connection with a technical product of about 91 p. c. ester content, Schimmel & Co. observed the following constants:

$d_{15^{\circ}}$ 0,9248; α_D + 0°; $n_{D20^{\circ}}$ 1,46456; soluble in 10 parts and more of 70 p. c. alcohol.

Like all formates, the ester is prone to decomposition.

Geranyl acetate.



Like linalyl acetate, geranyl acetate occurs rather commonly in volatile oils. It is the principal constituent of the oil of *Darwinia fascicularis*, and has also been found in the oils of the needles of *Callitris glauca*, palmarosa, lemongrass, sassafras leaves, kuromoji, geranium (?), petitgrain, neroli, coriander, *Eucalyptus Staigeriana*, *E. Macarthurii*, *Leptospermum Liveridgei* and lavender. Artificially geranyl acetate is obtained by heating geraniol with acetic acid anhydride and some anhydrous sodium acetate. In connection with a product obtained by this method, Bertram and Gildemeister¹⁾ observed:

B. p. 242 to 245° with decomposition (764 mm.); 127,8 to 129,2° (16 mm.); $d_{15^{\circ}}$ 0,9174; $n_{D15^{\circ}}$ 1,4628.

In connection with technical products of their own make Schimmel & Co. observed:

$d_{15^{\circ}}$ 0,910 to 0,917; α_D + 0°; $n_{D20^{\circ}}$ 1,462 to 1,466; soluble in 7 to 10 vol. of 70 p. c. alcohol.

The odor of geranyl acetate is pleasant and flower-like, reminding of that of linalyl acetate.

Citronellyl formate.



The formic ester of citronellol has thus far not been found in volatile oils. It is readily formed by boiling citronellol with

¹⁾ Journ. f. prakt. Chem. II. 49 (1894), 189.

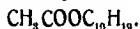
twice its volume of strong formic acid,¹⁾ also by setting aside for several days a solution of citronellol in anhydrous formic acid.²⁾

The ester decomposes readily, and according to Tiemann and Schmidt (*loc. cit.*) boils between 97 and 100° (10 mm.).

In connection with a technical product containing 93,2 p. c. of ester Schimmel & Co. observed the following properties:

$d_{15^{\circ}}$ 0,9105; α_D — 1°9'; $n_{D,20^{\circ}}$ 1,45111; soluble in 12,5 vol. of 70 p. c. and in 2,5 vol. of 80 p. c. alcohol.

Citronellyl acetate.



Citronellyl acetate is probably a constituent of citronella oil and oil of geranium, but its presence in either oil has not yet been definitely established. Artificially it can readily be obtained by the action of acetic acid anhydride on citronellol. It is a colorless liquid with a pleasant odor faintly resembling that of bergamot oil. According to Naschold³⁾ it boils at 121,5° under 15 mm. pressure. Tiemann and Schmidt⁴⁾ record the following properties:

B. p. 119 to 121° (15 mm.); $d_{17,5^{\circ}}$ 0,8928; $[\alpha]_{D,17,5^{\circ}}$ + 2,37°; $n_{D,17,5^{\circ}}$ 1,4456.

In the laboratory of Schimmel & Co. the following constants were observed:

$d_{15^{\circ}}$ 0,9013; α_D — 1°15'; $n_{D,20^{\circ}}$ 1,44891; soluble in 6 vol. of 70 p. c. alcohol.

Benzyl acetate.



Benzyl acetate is the principal constituent of the oil of jasmine flowers and of gardenia oil. It is also contained in ylang-ylang oil and in hyacinth oil. Artificially this ester can be obtained in a variety of ways. The simplest method is to acetylate

¹⁾ Walbaum and Stephan, Berl. Berichte 33 (1900), 2307.

²⁾ Tiemann and Schmidt, Berl. Berichte 29 (1896), 907.

³⁾ Beiträge zur Kenntnis aliphatischer Terpenverbindungen. Inaug.-Dissert. Göttingen 1896, p. 49.

⁴⁾ Loc. cit.

benzyl alcohol with acetic acid anhydride, or to act on benzyl alcohol with acetic acid in the presence of sulphuric acid.¹⁾ According to Seelig²⁾ a mixture of benzyl chloride, fused potassium or sodium acetate and glacial acetic acid are boiled for 20 to 30 hours in a flask connected with a reflux condenser. The latter is provided with a calcium chloride tube to keep out moisture. Tiemann³⁾ uses benzaldehyde as starting point which he gently boils with zinc dust and glacial acetic acid for about 12 hours in a flask connected with a reflux condenser.

Benzyl acetate is a colorless liquid of a refreshing odor reminding of jasmine. According to Hesse and Müller⁴⁾ it boils between 215 and 216° and has a specific gravity of 1.060 at 15°.

In connection with their own products prepared on a technical scale, Schimmel & Co. have observed the following constants: b. p. 215° (760 mm.), 95° (10 mm.), 69° (4 mm.); d_{15° 1.060 to 1.062; n_{D20° 1.502 to 1.504; ester content 98 to 100 p. c.; soluble in 2 vol. of 70 p. c., 6 vol. of 60 p. c., 20 vol. of 50 p. c., 70 vol. of 40 p. c., 120 vol. of 35 p. c., and 200 vol. of 30 p. c. alcohol.

The benzyl acetate content is the principal criterion as to the purity of the product. In as much as benzyl chloride may be used in its production, the absence of chlorinated products should be ascertained.

On account of its ready solubility in dilute alcohol, benzyl acetate is particularly adapted to the preparation of perfumes with low alcohol content.

Benzyl benzoate.



This ester is an essential constituent of cinnamon or Peru balsam oil. It likewise occurs in the oils of tuberose, ylang-ylang and tolu balsam.

According to Claisen,⁵⁾ benzyl benzoate can be prepared by dissolving 1½ g. of sodium in the requisite amount of benzyl

¹⁾ S. Cannizaro, Liebig's Annalen 88 (1853), 130.

²⁾ Journ. f. prakt. Chem. 39 (1889), 162.

³⁾ Berl. Berichte 19 (1886), 355.

⁴⁾ Berl. Berichte 32 (1899), 744.

⁵⁾ Berl. Berichte 20 (1887), 649.

alcohol to effect solution. 200 g. of benzaldehyde are then added and the mixture heated for several days on a water bath. The reaction product is acidulated with glacial acetic acid, the oil thrown out of solution with water and distilled.

Benzyl benzoate is a somewhat viscid colorless liquid which is difficultly volatile with water vapor and possesses a faint odor. At a low temperature it congeals to white crystals which melt again at about 20°. Claisen¹⁾ records the following properties:

M. p. 21°; b. p. 323 to 324°; d_{15}^{20} 1,1224 (liquid).

In the laboratory of Schimmel & Co. the following constants have been observed:

M. p. 19 to 20°; b. p. 156° (4,5 mm.); d_{15}^{20} 1,121 to 1,125; $n_{D,20}^{20}$ 1,569 to 1,570; soluble in 10 vol. of 80 p. c. and in 1,5 to 2 vol. of 90 p. c. alcohol.

In perfumery benzyl benzoate finds extensive application as solvent and fixing agent for other more volatile perfumes. Thus, e. g. it is used in making concentrated solutions of artificial musk.

Benzyl cinnamate.



Cinnamic acid benzyl ester, $C_{18}H_{16}O_2$, has been found in the oils of storax, tolu balsam and Peru balsam. According to Grimaux,²⁾ it can be obtained artificially by boiling sodium cinnamate, alcohol and benzyl chloride in a flask connected with a reflux condenser. It forms white, shiny crystals which possess an aromatic odor, boil at 39° and decompose at about 350°.³⁾ Occasionally it remains liquid for hours even at a temperature of 0°. When it congeals, the ester forms a wax-like looking mass of radiating crystals.

A product containing 98 p. c. of ester, when examined in the laboratory of Schimmel & Co., was found to possess the following properties:

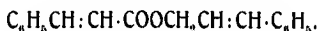
¹⁾ Berl. Berichte 20 (1887), 647.

²⁾ Compt. rend. 67 (1868), 1049.

³⁾ Grimaux, *Ibidem*, 1051.

M. p. 31,5 to 32,5°; b. p. 195 to 200° (5 mm.), 335 to 340° with decomposition (ordinary pressure);² soluble with slight turbidity in 7,5 vol. of 90 p. c. and in 1 vol. of 95 p. c. alcohol.

Cinnamyl cinnamate.



The cinnamyl ester of cinnamic acid, also known as styracin, $\text{C}_{18}\text{H}_{16}\text{O}_2$, is found in storax, also in the oils of hyacinth (?), xanthorrhæa resin, Peru balsam and Honduras balsam.

When pure it constitutes shiny white crystalline masses which melt at 44°,¹⁾ are insoluble in water, and rather difficultly soluble in alcohol. With water vapor the ester is difficultly volatile.

Of its derivatives the dibromide, $\text{C}_6\text{H}_5\text{CH}:\text{CH}\cdot\text{CO}_2\text{CH}_2\cdot\text{CHBr}\cdot\text{CHBr}\cdot\text{C}_6\text{H}_5$, which melts at 151° should be mentioned. According to Miller²⁾, it is obtained by adding bromine to an ethereal solution of styracin until it is no longer decolorized. After 24 hours the white powder that has been deposited is removed by filtration, washed with ether and recrystallized from hot alcohol.

Terpinyl formate.



Terpinyl formate possibly occurs in Ceylon cardamom oil, but its presence therein has not yet been definitely established. Artificially, the ester has been obtained by Lafont³⁾ who allowed two parts of lævogyrate turpentine oil to stand for several weeks with one part of crystallized formic acid. The product thus obtained revealed the following constants:

B. p. 135 to 138° (40 mm.); d_{20} 0,9986; $[\alpha]_D^{25}$ —69,25°.

Dextrogyrate turpentine yields the dextrogyrate ester with otherwise the same constants.

¹⁾ Miller, Liebig's Annalen 188 (1877), 202.

²⁾ Liebig's Annalen 189 (1877), 344.

³⁾ Compt. rend. 106 (1888), 140; Bull. Soc. chim. II. 49 (1888), 325.

Terpinyl acetate.

The acetate of terpineol has been found only occasionally in volatile oils: the dextrogyrate ester in cypress oil and the oil of Malabar cardamom, the inactive in oil of cajeput. It possibly, occurs also in Siberian pine needle oil and in the German oil from the needles of *Pinus silvestris*, and in niaouli oil. However, reliable data are still wanting.

Artificially, terpinyl acetate has been obtained by Bouchardat and Lafont¹⁾ by heating a mixture of pinene and acetic acid for 64 hours. According to Bertram²⁾ this reaction is accelerated greatly by the addition of small amounts of an inorganic acid. Likewise from terpineol and acetic acid anhydride a good yield of ester can be obtained by observing the proper conditions.

Terpinyl acetate is a colorless liquid of a relatively faint odor. According to the character of its source it is dextrogyrate, laevogyrate, or optically inactive. According to Bouchardat and Lafont (*loc. cit.*) it boils at 110 to 115° under 10 mm. pressure; and at 220° under ordinary pressure, but with partial decomposition. For a terpinyl acetate obtained by heating 1 vol. of oil of lemon with 1½ vol. of glacial acetic acid, Lafont³⁾ determined the following properties:

B. p. 140° (40 mm.); $d_{20} = 0.9828$; $[\alpha]_D + 52^\circ 30'$.

In the laboratory of Schimmel & Co. technical products with a 90 p. c. ester content have been found to possess the following properties:

B. p. 90 to 94° (5 mm.); $d_{15} = 0.9544$ to 0.961 ; $\alpha_D + 0^\circ$, $n_{D20} = 1.46526$ to 1.46585 ; soluble in about 5 vol. of 70 p. c. alcohol. Terpinyl acetate is rather difficultly saponifiable. Hence a large excess of alkali should be used in quantitative determinations and the mixture should be heated for two hours, for otherwise values will be obtained that are too low.

¹⁾ Annal. de Chim. et Phys. VI. 16 (1889), 244.

²⁾ G. I. P. 67255.

³⁾ Annal. de Chim. et Phys. VI. 15 (1888), 153.

Bornyl formate.

Bornyl formate occurs in valerian oil and possibly in the oil of *Achillea nobilis*. It results upon the interaction of borneol on formic acid in the presence of some mineral acid.¹⁾ It is a colorless liquid with a strong but pleasant odor. According to the borneol employed, the ester is either dextrogyrate or lævogyrate. The following constants have been recorded in chemical literature:

d-Bornyl formate:

B. p. 225 to 230°;²⁾ 98 to 99° (15 mm.); d_{15}° 1,017°).

B. p. 90° (10 mm.); d_{15}° 1,013; $[\alpha]_D + 31^{\circ}$; n_{D15}° 1,47078°).

B. p. 106 to 108° (21 mm.), 90° (10 to 11 mm.); d_{20}° 1,027, d_{22}° 1,009; $[\alpha]_D + 48^{\circ} 45'$.³⁾

l-Bornyl formate:

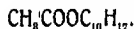
B. p. 106 to 108° (21 mm.); d_{15}° 1,026, d_{22}° 1,009; $[\alpha]_D - 48^{\circ} 56'$ (Béhal, *loc. cit.*).

B. p. 97° (15 mm.); $d_4^{20^{\circ}}$ 1,0058; $[\alpha]_D - 40,46^{\circ}$.⁴⁾

B. p. 215°; $[\alpha]_D - 49^{\circ}$ (4,55 p. c. solution in alcohol).⁵⁾

A technical product examined in the laboratory of Schimmel & Co. and containing 98,8° p. c. ester had the following properties:

B. p. 85 to 86° (7 mm.); d_{15}° 1,0126; $[\alpha]_D - 47^{\circ} 32'$.

Bornyl acetate.

This ester, which is a characteristic constituent of many coniferous oils, also occurs in several other oils. The dextrogyrate acetate occurs in the needle oil of *Callitris glauca*, the lævogyrate acetate in the needle oil of *Abies alba*, in the oil from the twigs

¹⁾ Bertram, G. I. P. 80711.

²⁾ Bruylants, Berl. Berichte 11 (1878), 455.

³⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 7.

⁴⁾ Bertram and Walbaum, Arch. der Pharm. 231 (1893), 305.

⁵⁾ Béhal, Annal. de Chim. et Phys. VII. 20 (1900), 421.

⁶⁾ Tschugaeff, Berl. Berichte 31 (1898) 1775.

⁷⁾ Minguin and de Bollemont, Compt. rend. 134 (1902), 609.

of *A. canadensis*, *A. balsamea* and Siberian pine needle oil, also in the oils of coriander, valerian and kessu root. The acetate has likewise been found in the following oils but observations as to its direction of rotation are wanting, viz., in the oil from the cones of *Abies alba* (?), the oil of *Pinus montana*, the oils from the cones and needles of *Picea canadensis* and *P. rubens*, the oil from the twigs and needles of *Larix americana*, in German and Swedish oils of *Pinus silvestris* (?), in the needle oil of *Picea nigra*, and in the oils from *Satureja Thymbra*, *Thymus capitatus* and golden rod.

The artificial preparation of bornyl acetate affords no difficulty. It can be obtained when borncol is acetylated in the ordinary manner, also by heating borneol with anhydrous acetic acid in the presence of some sulphuric acid.¹⁾

It is the only bornyl ester of a fatty acid which has thus far been obtained in a crystalline state. From petroleum ether it is obtained in handsome hemiedric crystals, which melt to a colorless liquid at 29°.²⁾ Molten bornyl acetate may remain in a liquid condition for a long time. Its aroma is typical of that of pine needles imparting to it its freshness and strength. The direction of rotation of the ester corresponds with that of the borncol. The following properties have been recorded:

M. p. 29°; b. p. 98° (10 mm.); d_{15}° 0.991; α_D — 38° 21'; n_{D15}° 1.46635;³⁾ b. p. 106 to 107° (15 mm.);⁴⁾

B. p. 107° (15 mm.); d_{15}° 0.9855; $[\alpha]_D$ — 44.40°;⁵⁾

d_{15}° 0.9908; α_D — 43° 40'; n_{D15}° 1.46387; d_{15}° 0.9912; α_D — 43° 40'; n_{D20}° 1.46446; soluble in 2.7 vol. of 70 p. c. alcohol; m. p. 28.5°; d_{15}° 0.9912; α_{D15}° + 40° 28'; n_{D20}° 1.46397; soluble in 3 vol of 70 p. c. alcohol.⁶⁾

In connection with two liquid commercial products Schimmel & Co. observed the following properties:

d_{15}° 0.9905; α_D — 2° 22'; and d_{15}° 0.9901; α_D + 29° 4'.

¹⁾ G. I. P. 80711.

²⁾ Bertram and Walbaum, Arch. der Pharm. 331 (1893), 304.

³⁾ Bertram and Walbaum, *Ibidem* 305.

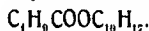
⁴⁾ Bertram and Walbaum, Journ. f. prakt. Chem. II. 49 (1894), 7.

⁵⁾ Tschugaeff, Berl. Berichte 31 (1898), 1775.

⁶⁾ Observations made by Schimmel & Co.

For the identification of bornyl acetate, fraction 220 to 230° is employed. It is strongly chilled and inoculated with a little solid bornyl acetate. If the desired results are not thus obtained, the sample in question is saponified and the components identified.

Bornyl isovalerate.



Bornyl *isovalerate* occurs in oil of valerian and in kesso root oil. In the latter it is found in the *lavogyrate* modification. Artificially it is obtained by the esterification of borneol with *isovaleric* acid. It is a colorless, aromatic liquid, the odor and taste of which remind both of valerian and borneol. According to Bruylants¹⁾ it boils between 255 and 260°.

In connection with technical products showing an ester content of 86 to 89%, Schimmel & Co. observed the following constants:

d_{15}^0 , 0.954 to 0.955; α_D , $-34^{\circ}25'$ to $-35^{\circ}31'$; n_{D20}^0 , about 1.462; soluble in about 4 vol. of 80 p. c. alcohol.

For its quantitative saponification, heating for two hours with a large excess of potassa is required.

Bornyl *isovalerate* is reputed to produce good results in all sorts of nervous troubles, especially in nervous heart affections. It is also said to stimulate the appetite.

Menthyl acetate.



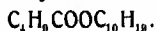
Menthyl acetate, a liquid having a peppermint-like odor, has thus far been observed only in oil of peppermint. It can readily be obtained by boiling menthol with acetic acid anhydride and some sodium acetate. Its properties are:

B. p. 227 to 228°; d_{20}^{20} , 0.925; $[\alpha]_D$, -79.26° .²⁾
 d_{15}^0 , 0.9296 to 0.9298; α_D , $-72^{\circ}47'$ to $-73^{\circ}18'$; n_{D20}^0 , 1.44669 to 1.44680; soluble in about 15 vol. of 65 p. c. and in about 6 vol. of 70 p. c. alcohol.³⁾

¹⁾ Berl. Berichte 11 (1878), 456.

²⁾ Kishner, Journ. russ. phys. chem. Ges. 27 (1895), 480.

³⁾ Observation in the laboratory of Schimmel & Co.

Menthyl isovalerate.

Up to the present time this ester has been found only in American peppermint oil. It is a colorless liquid the odor of which reminds of both components. Artificially it is obtained by the esterification of menthol with *isovaleric acid*. In connection with technical products thus obtained and containing about 80 p. c. ester, Schimmel & Co. observed the following properties:

d_{15}^0 , 0,9067 to 0,908; n_D^{20} , $-56^{\circ}28'$ to $-56^{\circ}51'$; $n_{D^{20}}^{1,44851}$ to 1,44861; soluble in 5 to 7 vol. of 80 p. c. alcohol.

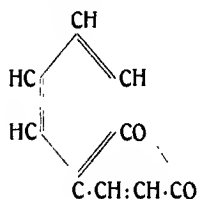
This ester also is saponifiable with difficulty. For quantitative determinations the process of heating on the water bath with the excess of alkali should be extended over two hours.

Menthyl *isovalerate* has been recommended as analeptic and antineuralgic. It is also reported to have been effective in the treatment of sea sickness.

LACTONES.

Lactones also have been found in volatile oils. Some of them, like scdanolid, coumarin, and hydrocoumarin are characterized by a strong odor. Alantolactone and the lactone $C_{10}H_{16}O_2$ from peppermint oil have but a faint odor.

In this connection only two of the most important, *viz.*, coumarin and alantolactone, are to be considered.

Coumarin.

Coumarin (o-hydroxycinnamic acid anhydride), $C_9H_6O_2$, the odoriferous principle of the "Waldmeister" (*Asperula odorata*), is widely distributed in the vegetable kingdom. It was first observed in the tonka beans, the fruit of *Dipteryx odorata* in which it occurs in largest amount. Later it was found in the "Waldmeister", also in dates, in Peru balsam, in the salikounda beans of *Copeifera Salikounda*, in lavender oil, in the bulbs of *Vitis sessilifolia*, in the resin and bark of *Ceratopetalum apetalum* also in the following plants: *Adiantum pedatum*, *A. peruvianum*, *A. trapeziforme*, *Anthoxanthum odoratum*, *Cinna arundinacea*, *Hierochloa alpina*, *H. australis*, *H. borealis*, *Milium ellusum*, *Aceras anthropophora*, *Angræcum lragrans*, *Nigritella angustilolia*, *Orchis lusca*, *Orchis militaris* (?), *Herniaria glabra*, *Achlys triphylla*, *Prunus Mahaleb*, *Ruta graveolens*, *Dipteryx odorata*, *D. oppositifolia*, *D. pteropus*, *Melilotus alba*, *M. altissima*, *M. hamata*, *M. leucantha*, *M. ollicinalis*, *Chrysophyllum imperialis*, *Peristrophe angustilolia*, *Alyxia stellata*, *Galium triflorum*, *Spermacoce semirecta*, *Liatris odoratissima*, *L. spicata*, *Ageratum mexicanum*, *A. conyzoides*, *Eupatorium Ayapana* and *E. alricanum* (?).¹⁾ As melilotate, coumarin also occurs in *Lindsaya cultrata* and in *Melilotus ollicinalis*. Apparently coumarin does not always exist as such in the plant, but is frequently formed by ferment action since its odor often becomes noticeable only after drying. Synthetically it was obtained by Perkin²⁾ by the action of acetic acid anhydride and sodium acetate on salicylic aldehyde. However, it is also obtained by other methods and in recent years has constituted an important article of chemical industry.

Coumarin forms colorless, shiny laminæ or rhombic prisms and possesses a pleasant, spicy odor and a bitter taste. In

¹⁾ Literature: Bley, Arch. der Pharm. 142 (1857), 32; Poulsen, Bot. Zentralbl. 15 (1883), 415; Lojander, Just Jahresbericht 1887, Bd. I. 181; Mollsch and Ziesel, Berichte d. deutsch. botan. Gesellschaft 6 (1888), 353; Greshoff, Berichte d. deutsch. pharm. Ges. 9 (1899), 214; Peckolt, Zeitschr. d. allg. österr. Apoth. Ver. 31 (1893), 829; Molisch, Apotheker Ztg. 17 (1902), 45, 137; Busse, Berichte d. deutsch. pharm. Ges. 14 (1904), 205; Peckolt, *Ibidem* 45; Senft, Pharm. Zentralh. 45 (1904), 599; Tschirch, *Ibidem* 46 (1905), 803; Schimmel's Bericht April 1889, 46; October 1889, 58; Report of Schimmel & Co. April 1890, 66; October 1900, 79; April 1902, 93.

²⁾ Berl. Berichte 8 (1875), 1599.

extreme dilution its odor resembles that of new mown hay. According to Zwenger and Dronke it melts at 67° .¹⁾ Schimmel & Co. observed the melting point of 69 to 70° in connection with the best commercial products. It sublimes without decomposition and boils at $290,5$ to 291° .²⁾

Coumarin dissolves difficultly in cold, somewhat more readily in hot water, easily in alcohol, and ether and in volatile and fatty oils. As to its solubility in alcohol of different strengths, Schimmel & Co. have made the observations recorded in the following table.³⁾

| 100 parts alcohol | at 0° C. | at 16 to 17° C. | at 29 to 30° C. |
|---------------------|-------------------|----------------------------|----------------------------|
| of 90 vol.-percent. | 7,1 parts | 13,7 parts | 42,5 parts |
| of 80 vol.-percent. | 6,0 parts | 12,3 parts | 38,3 parts |
| of 70 vol.-percent. | 4,4 parts | 9,1 parts | 26,0 parts |
| of 60 vol.-percent. | 3,2 parts | 6,0 parts | 16,0 parts |
| of 50 vol.-percent. | 1,7 parts | 3,4 parts | 8,9 parts |
| of 40 vol.-percent. | 0,7 parts | 1,5 parts | 3,9 parts |
| of 30 vol.-percent. | 0,3 parts | 0,6 parts | 1,7 parts |
| of 20 vol.-percent. | 0,2 parts | 0,4 parts | 0,8 parts |
| of 10 vol.-percent. | 0,15 parts | 0,25 parts | 0,5 parts |
| 100 parts water | 0,12 parts | 0,18 parts | 0,27 parts |

When boiled with concentrated potassa solution, coumarin is hydrolyzed to *o*-coumaric acid, $\text{HO} \cdot \text{C}_6\text{H}_4 \cdot \text{CH} : \text{CH} \cdot \text{COOH}$, which melts at 207 to 208° . When fused with potassium hydroxide it yields salicylic acid (m. p. 156 to 157°). When reduced with sodium amalgam, methylotic acid, $\text{HO} \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{COOH}$ (m. p. 81°) is obtained, whereas reduction with sodium and alcohol yields a phenol alcohol, *o*-hydroxydihydrocinnamic alcohol, the

¹⁾ Liebig's Annalen 123 (1862), 148.

²⁾ Perkin, Liebig's Annalen 147 (1868), 232.

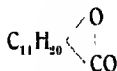
³⁾ Report of Schimmel & Co. April 1889, 66.

benzoyl compound of which melts at 99 to 100°.¹) Bromine adds to form dibromcoumarin melting at 100°.²)

Coumarin and its solutions should be kept in a cool, dark place. In the course of even a few weeks light colors it yellow with polymerization to hydrocoumarin melting at 262°.³) which is an odorless compound difficultly soluble in alcohol.

When ascertaining its purity, the determination of its melting point is of first importance, then that of its solubility in various solvents. Adulteration with acetanilid has been observed repeatedly. A method for the quantitative determination of coumarin in the presence of vanillin and acetanilid has been worked out by Winton and Bailey.⁴)

Alantolactone.



The commercial helenin,⁵) also known as alant camphor, is chemically alantolactone and is the principal constituent of the oil of elecampane root (from *Inula Helenium*).

Kallen⁶) originally regarded it as alantic acid anhydride, whereas Bredt and Posth⁷) recognized its lactone character and changed the name accordingly to alantolactone.

Recrystallized from dilute alcohol, alantolactone is obtained in colorless, prismatic needles which melt at 76°⁸) and which

¹) Semmler, Berl. Berichte 39 (1906), 2856.

²) Perkin, Liebig's Annalen 157 (1871), 116.

³) Ciamician and Silber, Berl. Berichte 35 (1902), 4130; 36 (1903), 4266.

⁴) Pharmaceutical Journ. 75 (1905), 476.

⁵) The name helenin is applied to no less than three different substances. Gerhardt [Annal. de Chim. et Phys. II. 72 (1839), 163 and III. 12 (1844), 188; Liebig's Annalen 34 (1840), 192 and 52 (1844), 389] applied the name to his impure alantolactone. Kallen [Berl. Berichte 6 (1873), 1506; compare also Kallen, *Über Alantolacton und die Anlagerung von Blausäure an ungesättigte Lactone*, Inaug.-Dissert. Rostock 1895] applied it to an impure alantolactone contaminated with traces of oil of elecampane. Finally, the name is also applied to the inulin of the elecampane root. The helenin of commerce is well nigh pure alantolactone.

⁶) Berl. Berichte 9 (1876), 154.

⁷) Liebig's Annalen 245 (1895), 349.

⁸) Most of the commercial products reveal a somewhat lower melting point.

possess a slight odor and taste. It sublimes when only moderately heated and boils at 275° with partial decomposition. Under 10 mm. pressure it boils at 192° .¹⁾ Even in hot water it is but sparingly soluble, but readily in alcohol, ether, chloroform, glacial acetic acid, benzene and petroleum ether. Cold sodium carbonate solution does not dissolve it. When gently heated with dilute alkalies it dissolves forming solutions of the salts of the corresponding hydroxy acid, the alantonic acid, $C_{14}H_{20} \cdot OH \cdot COOH$. From these solutions the lactone is precipitated upon the addition of mineral acids. Characteristic derivatives of alantolactone are its monochlorhydrate, m. p. 117° , the monobromhydrate, m. p. 106° , the dichlorhydrate, m. p. 127 to 134° , and the dibromhydrate, m. p. 117° .

Alantolactone is accompanied by a small amount of a substance which Kallen designated helenin and which was later isolated by Sprinz²⁾ and studied more carefully by him. Because of the same elementary composition with alantolactone, $C_{14}H_{20}O_2$, and because of its chemical behavior, Sprinz has named this compound isalantolactone. When pure it forms white prisms which melt at 115° , and which dissolve in benzene, ether, chloroform and absolute alcohol. In contrast to the behavior of alantolactone, it crystallizes unchanged from hot soda solution. It is only after boiling for about 5 to 6 hours that it is changed to the sodium salt of isalantonic acid which is precipitated from the solution when acidulated with hydrochloric acid. When melted this loses water and is reconverted to isalantolactone.

Medicinally, alantolactone is used as internal antiseptic. Added to urine it prevents putrefaction even in dilutions of 1:10000.

¹⁾ Bredt and Posth, Liebig's Annalen 285 (1895), 349.

²⁾ Arch. der Pharm. 289 (1901), 201.

OXIDES.

Oxides have been found in volatile oils in isolated cases only, those of the aliphatic series having not yet been observed. Of synthetic products, however, several are known. Of special importance is the *pinol*, $C_{10}H_{16}O$, which is closely related to pinene.

It is obtained as a by-product in the preparation of pinene nitrosochloride. It is also formed when pinolhydrate (sobrcrol) is heated with dilute sulphuric acid¹⁾ or terpineol dibromide with sodium alcoholate.²⁾

According to Wagner and Slawinsky,³⁾ an optically active pinol can be obtained when hypochlorous acid is allowed to act on pinene and subsequent reduction of the *cis*-pinolglycol-2-chlorhydrin, in alcoholic solution, with zinc dust.

Pinol is a liquid which boils at 183 to 184° and possesses an odor resembling that of cineol and camphor. $d_{20} 0.9455$; $n_{D20} 1.47096$. It is very stable toward reducing agents and can be distilled over sodium without decomposition. When oxidized with permanganate or dilute nitric acid it is converted into terebic acid (m. p. 175 to 176°). Inorganic acids react with pinol forming cineol. Bromine is added forming a dibromide which melts at 94° and which is suited to its identification.

Another artificially prepared oxide is the

1,4-Cineol which, together with terpineol, is formed when 1,4-terpin is heated with oxalic acid. It is a liquid which boils at 172 to 173° and which, unlike cineol, does not congeal when cooled. $d 0.987$; $n 1.4485$.⁴⁾

Prieschajew⁵⁾ has succeeded in preparing the oxides of a number of so-called terpene alcohols, and other terpene compounds the properties of which are indicated in the following table:

¹⁾ Wallach, Liebig's Annalen 250 (1890), 315.

²⁾ Wallach, *Ibidem* 277 (1893), 115.

³⁾ Berl. Berichte 32 (1899), 2070.

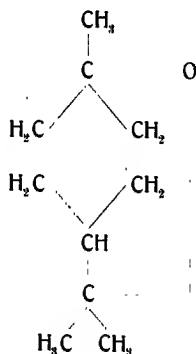
⁴⁾ Wallach, Liebig's Annalen 356 (1907), 205.

⁵⁾ Berl. Berichte 42 (1909), 4811.

| | boil. point | $d_{40}^{0^{\circ}}$ | $d_{10}^{18^{\circ}}$ | $n_{D16}^{20^{\circ}}$ | |
|-------------------|-------------------------|----------------------|-----------------------|------------------------|--|
| Geraniol monoxyde | 157 to 168° (25 mm.) | 0,9716 | 0,9610 | 1,4681 | When hydrated, a glycerol, b. p. 205 to 207° (20 mm.) results |
| Geraniol dioxyde | 180 to 183° (25 mm.) | 1,0587 | 1,0472 | 1,4653 | When hydrated, a glycerol oxyde, b. p. 220° (15 mm.), m. p. 137 to 138° results |
| Linalool monoxyde | 95° (25 mm.) | 0,9660 | 0,9507 | 1,4554 | $[\alpha]_D - 4,98^{\circ}$. Hydration yields a two-fold unsaturated aldehyde, b. p. 120 to 122° (25 mm.), m. p. of the semicarbazone 138,5°. |
| Linalool dioxyde | 131 to 133° (25 mm.) | 1,0552 | 1,0423 | 1,4616 | When hydrated, there results a glycerol oxyde, b. p. 210 to 212° (25 mm.) |
| Citral oxyde | 146 to 148° (20 mm.) | 1,0091 | 0,9740 | 1,4604 | When hydrated, there results a glycol aldehyde, b. p. 141 to 142° (24 mm.) |
| Citronellal oxyde | 130 to 131° (25 mm.) | 0,9437 | 0,9344 | 1,4421 | Upon hydration there results a glycol aldehyde, b. p. 180 to 182° (18 mm.) |
| Limonene monoxyde | 113 to 114° (50 mm.) | 0,9435 | 0,9303 | 1,4693 | $[\alpha]_D - 6,76^{\circ}$. Upon hydration there results a glycol, m. p. 66,5 to 67,5°. |
| Limonene dioxyde | 146,5 to 147° (50 mm.) | 1,0471 | 1,0338 | 1,4702 | $[\alpha]_D + 52,23^{\circ}$. Upon hydration there results an anisophous erythrol, b. p. 220° (23 mm.) |
| Pinene oxyde | 102 to 103° (50 mm.) | 0,9812 | 0,9689 | 1,4708 | $[\alpha]_D - 92^{\circ}$. Upon hydration pinol hydrate results. |

Wellnigh the only oxide which occurs in volatile oils is cineol.

Cineol.



Cineol (eucalyptol), $C_{10}H_{18}O$, is very widely distributed. It is the principal constituent of the oil of *Eucalyptus Globulus*, of cajeput oil, niaouli oil and of the oil of wormseed. In varying amounts it has also been found in American wood turpentine oil, Java "lemon olie", safran oil, oil of zedoary oil of galangal, ginger oil, oil of paradise grains (?), Ceylon, Bengal, Malabar and Kamarun cardamom oil, in the oil from the fruit of *Amomum Mala*, in matico oil, betel oil, star anise oil, in Japanese star anise oil, magnolia oil, kobuschi oil, boldo leaf oil, camphor oil, in the oil from the leaves of *Laurus Camphora*, in cinnamon root oil, in the bark oil from *Cinnamomum Oliveri*, in nikkei oil, in apopin oil, in laurel leaf oil, in the oil of laurel berries, in the leaf oil from *Tetranthera polyantha* var. *citrata*, in the oil of *Umbellularia californica*, in the bark oil of *Ocotea usamaharensis*, in kuromoji oil, in carqueja oil, in the oils of rue, canella alba, myrtle, cheken leaf, and pimenta, in the oils of *Melaleuca acuminata*, *M. linariifolia*, *M. nodosa*, *M. thymifolia* and *M. uncinata*, in the oils of *Eucalyptus acmenioides*, *E. allinis*, *E. albens*, *E. amygdalina*, *E. angophoroides*, *E. apiculata*, *E. Bæuerleni*, *E. Behriana*, *E. bicolor*, *E. Bosistoana*, *E. botryoides*, *E. bridgesiana*, *E. Cambagei*, *E. camphora*, *E. capitellata*, *E. carnea*, *E. cinerea*, *E. cneorilolia*, *E. conica*, *E. cordata*, *E. coriacea*, *E. corymbosa*, *E. crebra*, *E. Dawsoni*, *E. dealbata*, *E. dumosa*, *E. engenioides*, *E. fastigata*, *E. fraxinoides*, *E. gonio-calyx*, *E. gracilis*, *E. hæmastoma*, *E. hemilampra*, *E. hemiphloia*, *E. intermedia*, *E. lactea*, *E. longifolia*, *E. Luehmanniana*, *E. macrorhyncha*, *E. maculata*, *E. maculosa*, *E. Maideni*, *E. melanophloia*, *E. melliodora*, *E. microcorys*, *E. microtheca*, *E. Morrisii*, *E. nigra*, *E. obliqua*, *E. odorata*, *E. oleosa*, *E. oreades*, *E. ovalifolia*, *E. o. var. lanceolata*, *E. paludosa*, *E. paniculata*, *E. pendula*, *E. piperita*, *E. polyanthema*, *E. polybractea*, *E. populifolia*, *E. propinqua*, *E. pulverulenta*, *E. punctata*, *E. p. var. didyma*, *E. quadrangulata*, *E. radiata*, *E. resinifera*, *E. Risdoni*, *E. robusta*, *E. Rossei*, *E. rostrata*, *E. r. var. borealis*, *E. rubida*, *E. saligna*, *E. siderophloia*, *E. sideroxylon*, *E. s. var. pallens*, *E. Smithii*, *E. squamosa*, *E. stricta*, *E. Stuartiana*, *E. tessellaris*, *E. tereticornis*, *E. t. var. linearis*, *E. trachyphloia*, *E. umbra*, *E. viminalis*, *E. v. var. « virgata*, *E. viridis*, *E. vitrea*, *E. Wilkinsoniana* and *E. Woollsiana*, in the oils from the leaves of *Vitex Agnus Castus*,

and *V. trilolia*, in the oils of rosemary, lavender and spike, also in the oils of *Lavandula dentata*, *L. pedunculata*, *L. Stoechas*, in sage oil, in Spanish majoran oil, in American, French and Russian peppermint oils, in spearmint oil, in Java- and Réunion basilicum oil, in the oils of *Blumea balsamifera*, *Osmitopsis asteriscoides* (?), *Achillea millefolium*, *A. moschata*, *Artemisia vulgaris*, *A. frigida*, *A. Herba-alba*, *A. Leudoviciana* and in yomugi oil.

The preparation of this substance from oils, such as the oil of *Eucalyptus Globulus* rich in cineol is not difficult, since the cineol, purified as carefully as possible by fractional distillation, crystallizes in the cold. For the identification or isolation of small amounts of cineol, the hydrogen chloride addition product, or better still that with hydrogen bromide, is resorted to. Upon decomposition with water both yield cineol.

As a product of molecular rearrangement, cineol results when terpineol, or terpin hydrate, is boiled with dilute acids.

Pure cineol is a colorless, optically inactive liquid, the odor of which resembles that of camphor and which crystallizes in the cold. For the cineol regenerated from its chlorhydrate, Wallach¹⁾ observed the following constants:

B. p. 176; d_{20} , 0.9267; n_D , 1.45839.

In connection with products obtained on a technical scale, Schimmel & Co. observed:

Congeeing point about $+1^\circ$; m. p. between $+1$ and $+1.5^\circ$; b. p. 176 to 177° (764 mm.); d_{15} , 0.928 to 0.930; $n_{D,20}$, 1.456 to 1.459; soluble in about 12 vol. of 50 p. c., in 4 vol. of 60 p. c. and in 1.5 to 2 vol. of 70 p. c. alcohol.

Cineol yields characteristic, loose addition products with bromine, iodine, chlorine and hydrogen bromide,²⁾ phosphoric acid, arsenic acid, α - and β -naphthol, iodol and resorcinol. Some of them can be utilized for isolating and characterizing cineol. The resorcinol compound is also adapted to the quantitative determination of cineol. (Compare the chapter "The examination of volatile oils".) Dehydrating agents convert cineol into dipentene,³⁾

¹⁾ Liebig's Annalen 245 (1888), 195.

²⁾ Liebig's Annalen 225 (1884), 300, 303; 230 (1885), 227; 246 (1888), 280.

³⁾ Wallach and Brass, Liebig's Annalen 225 (1884), 310.

other suitable reagents convert it directly into derivatives of dipentene. Thus e. g. dipentene dihydriodide results when dry hydrogen iodide is passed into cineol. The oxygen of the cineol is of the oxide type, hence it does not react with hydroxylamine or phenylhydrazine, neither does metallic sodium act on it. Hence cineol can be distilled without decomposition over metallic sodium.

When oxidized with potassium permanganate and the aid of heat, cineol yields the dibasic cineolic acid,¹⁾ $C_{10}H_{16}O_8$, m. p. 196 to 197°. Acetic acid anhydride dehydrates this dibasic acid to its anhydride, which, in turn, upon destructive distillation yields methyl heptenone, $C_8H_{14}O$, which likewise occurs in nature.

Toward reducing agents cineol is very stable. Molle²⁾ found that hydrogen iodide only will reduce it. When heated with this reagent for an hour in a sealed tube to 220 to 225° with the addition of metallic mercury as iodine binding agent, cineol yielded a hydrocarbon $C_{10}H_{18}$ (b. p. 165 to 170°; $d_{15} 0.8240$; $n_D^{20} 1.45993$) which Molle named cineolene, and a polymeric hydrocarbon $(C_{10}H_{16})_n$.

Cineol has a characteristic odor which usually directs attention to its presence in mixtures. For its ready detection Hirschsohn's³⁾ iodol reaction can be employed. A small amount of iodol is dissolved with the aid of gentle heat in a few drops of the oil to be tested. If cineol be present the equimolecular addition product of the components crystallizes out. Recrystallized from alcohol or benzene this melts at about 112°.⁴⁾

If cineol is to be isolated as such, dry hydrogen bromide is passed into the well cooled petroleum ether solution (equal volumes) of the cineol fraction. The white crystalline precipitate resulting is removed by suction and washed with petroleum ether. The hydrobromide thus obtained is fairly stable, melts at 56 to 57°. Water readily breaks it up into cineol and hydrogen bromide.

In the presence of a sufficient cineol content, resorcin can be used to advantage for its isolation. For this purpose the

¹⁾ Wallach and Gildemeister, *Liebig's Annalen* 246 (1888), 268.

²⁾ *Über die Zusammensetzung des ätherischen Lorbeeröles und zur Kenntnis seines Hauptbestandteils, des Cineols*, Inaug.-Dissert. Basel 1904, p. 62. Comp. also Thoms and Molle, *Arch. der Pharm.* 242 (1904), 181.

³⁾ *Pharm. Zeitschr. f. Russland* 32 (1893), 49, 67.

⁴⁾ Bertram and Walbaum, *Arch. der Pharm.* 235 (1897), 178.

cineol fraction is stirred with two volumes of a 50 p. c. resorcinol solution. If necessary a small amount of cineol resorcinol is added. The resulting addition product, consisting of 1 mol. resorcinol and 2 mol. cineol,¹⁾ is removed by suction, pressed between filter paper and decomposed with alkali. Cineol resorcinol crystallizes in needles that melt at about 80°. They are readily soluble in alcohol, ether and benzene, but very difficultly in petroleum ether and water. It is relatively much more stable than the addition product of phosphoric acid to cineol, which is also used for the isolation of the latter. However, it also decomposes gradually with the liberation of cineol when exposed to the air more readily in vacuum — so that finally resorcinol alone remains. The same change can be observed when cineol resorcinol is heated with water or petroleum ether,²⁾ or even when the compound is washed with these solvents. Dry and well crystallized, cineolresorcinol can be obtained by crystallizing 1 part of resorcinol from 10 parts of cineol (Baeyer and Villiger, *loc. cit.*).

For further characterization cineol can be oxidized with potassium permanganate to cineolic acid.

Cineol possesses antiseptic properties. In medicine it finds external as well as internal application, the latter e. g. as vermifuge. Toxic results have been observed in connection with cineol or eucalyptus oils only then when larger amounts were administered.

The only other oxide found in volatile oils is the *Carlina oxide*, $C_{13}H_{10}O$, which constitutes the principal constituent of the carline thistle. It is probably phenyl-1- α -furyl-3-allene.³⁾

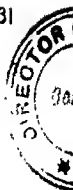
B. p. 167 to 168 (20 mm); d_4^{20} 1.066; n_D^{20} 1.586.

When oxidized with potassiumpermanganate, it yields quantitatively benzoic acid; when reduced with sodium and alcohol, tetrahydrocarlina oxide, $C_{13}H_{14}O$, which is oxidized by potassium permanganate to γ -phenylbutyric acid, m. p. 52°.

¹⁾ Baeyer and Villiger, Berl. Berichte 35 (1902), 1209.

²⁾ Report of Schimmel & Co. October 1907, 47.

³⁾ Semmler, Berl. Berichte 33 (1900), 726; Semmler and Ascher, *Ibidem* 42 (1909), 2355.



NITROGEN- AND SULPHUR-CONTAINING COMPOUNDS.

Compounds containing nitrogen or sulphur are frequently obtained during the distillation of such parts of plants which are rich in albuminous substances (protoplasm) or similar bodies, e. g. during the distillation of fresh herbs and seeds. The readily volatile compounds, ammonia, trimethylamine, sulphureted hydrogen and hydrocyanic acid largely escape during the process of distillation. Smaller amounts are dissolved in the aqueous distillate. Rarely do they enter into combination with constituents of the volatile oil in the preparation of which they are produced.

Ammonia is produced during the distillation of many drugs, e. g. that of eubebs, pepper, pimento, ginger, &c. Möslinger¹⁾ found ammonia in the aqueous distillate of heracleum oil.

Narcotic smelling bases were observed by Selimel & Co. in connection with caraway oil and the oils of other umbelliferous fruits²⁾, also in connection with patchouli oil³⁾ and the oil of *Barosma pulchellum*.⁴⁾

NITRILES.

Hydrocyanic acid.

The principal representative of the nitriles is that of formic acid, viz., hydrogen cyanide, HCN. It is formed during the production of the oils of bitter almond and cherry laurel, but also occurs in the distillates of a large number of plants.⁵⁾

¹⁾ Liebig's Annalen 185 (1877), 37.

²⁾ Report of Schimmel & Co. April 1905, 20.

³⁾ *Ibidem* April 1904, 70; April 1905, 60.

⁴⁾ *Ibidem* April 1909, 95.

⁵⁾ *Verslag omtrent den staat van 's lands Plantentuin te Buitenzorg over het jaar 1899*, 29; 1897, 37; Greshoff, Distribution of prussic acid in the vegetable kingdom, British Association, York 1906; Arch. der Pharm. 244 (1906), 397, 665; Weehuizen, Pharm. Weekblad 43 (1906), 907; Guignard, Compt

According to data found in phytochemical literature the following plants yield hydrogen cyanide only: *Hygrophorus agathomus*, *H. cerasinus* (?), *Marasmius oreades*, *Pholiota radicata*, *Russula lactens*, *Gymnogramme aurea*, species of *Lastrea* and *Athyrium*, *Triglochin palustris*, *T. maritima*, *Scheuchzeria palustris*, *Glyceria aquatica*, *Sorghum halepense*, *S. nigrum*, *S. vulgare*, *Stipa hystrix*, *St. leptostachya*, *St. tortilis*, *Gynerium argenteum*, *Melica altissima*, *M. ciliata*, *M. nutans*, *M. uniflora*, *Zea Mays*, *Briza minor*, *Lamarkia aurea*, *Holcus lanatus*, *Poa pratensis*, *Festuca Poa*, *Arum maculatum*, *Alocasia Veitchii*, *Colocasia gigantea*, *Cyrtosperma lasioides*, *C. Merksii*, *Lasia aculeata*, *L. Zollingeri*, *Salix triandra* (*amgdalina*), *Sponia virgata*, *Aquilegia chrysantha*, *A. vulgaris*, *Thalictrum aquilegifolium*, *Ranunculus arvensis*, *R. repens*, *Nandina domestica*, *Lepidium sativum* (?), *Ribes aureum*, *R. rubrum*, *Grossularia nigrum*, *Lotus arabicus*, *L. australis*, *Phaseolus lunatus*, *P. Mungo*, *Cicer arietinum*, *Dolichos Lablab*, *Linnm peregrine*, *L. usitatissimum*, *Citrus medica* (?), *Chaetelia cymosa*, *Bridelia ovata*, *Elateriospermum Tapos*, *Hevea brasiliensis*, *H. Spruceana*, *Jatropha angustifolia*, *Manihot Bankensis*, *M. Glaziovii*, *M. palmata*, *M. utilis*, *Ricinus communis*, *Kurriina ceylanica*, *Cupania spec.*, *Rhamnus frangula*, *Sterculia spec.*, *Gynocardia odorata*, *Hydnocarpus alpinus*, *H. anthelmintica*, *H. inebrians*, *Kiggeleia africana*, *Pongium ceramense*, *P. edule*, *Ryparosa cecilia*, *R. longipedunculata*, *Taraktogenos Blumei*, *T. Kurzii*, *Trichadenia ceylanica*, *Psidium montanum* (?), *Combretum constrictum* (?), *Homalium (Blackwellia) tomentosum*, *Tacsonia spec.*, *T. Van-Volxemii*, *Modorra Wightiana*, *Ophiocaulon gummifer*, *Passiflora alata*, *P. caerulea*, *P. edulis*, *P. lictida*, *P. hybrida*, *P. laurifolia*, *P. maculata*, *P. Princeps*, *P. quadrangularis*, *P. suberosa*, *Ipomoea obscura*, *Isonandra (Bassia) Mottleyana* (?), *Paysonia latifolia*, *Merremia vitifolia*, *Osmohydrophora nocturna* (?), *Aplotaxis candicans*, *Centaurea montana*, *C. solstitialis*, *Pyrethrum caucasicum*, *Dimorphoteca pluvialis*, *Cirsium arvense*.

rend. 143 (1906), 451; Hérissey, Journ. de Pharm. et Chim. VI. 24 (1906), 350, 537; Jitschy, *ibidem* 355; Hébert, Bull. Soc. chim. III. 35 (1906), 919; Bertrand, Compt. rend. 143 (1906), 832; Guignard, Bull. Sciences pharmacol. 13 (1906), 603; Dunstan and Henry, Annal. de Chim. et Phys. 10 (1907), 118; Greshoff, Pharm. Weekblad 45 (1908), 770.

Hydrocyanic acid and benzaldehyde are yielded by the following plants: *Pteris aquilina*, *Panicum inaximum*, *P. muticum*, *Ximenia americana*, *Amelanchier alnifolia*, *A. canadensis*, *A. vulgaris*, *Chamaemeles coriacea*, *Crataegus orientalis*, *C. oxyacantha*, *Eriobotrya japonica*, *Nuttallia cerasiformis*, *Osteomeles spec.*, *Photinia arbutifolia*, *P. Benthiana*, *P. serrulata*, *P. variabilis*, *Pyrus americana*, *P. Aria*, *P. Aucuparia*, *P. Cydonia*, *P. germanica*, *P. japonica*, *P. Malus*, *P. mespilus*, *P. pinnatifida*, *P. Ringo*, *P. spectabilis*, *P. torminalis*, *Prunus adenopoda*, *P. americana*, *P. Amygdalus*, *P. alleghaniensis*, *P. Armeniaca*, *P. avium*, *P. Besseyi*, *P. Capollin*, *P. caroliniana*, *P. Cerasus*, *P. Chamaecerasus*, *P. divaricata*, *P. domestica*, *P. javanica*, *P. Laurocerasus*, *P. lusitanica*, *P. nana*, *P. occidentalis*, *P. Padus*, *P. paniculata*, *P. pendula*, *P. pennsylvanica*, *P. Puddum*, *P. serotina*, *P. sphaerocarpa*, *P. spinosa*, *P. subhirtella*, *P. undulata*, *P. virginiana*, *P. Persica*, *Cotoneaster allinis*, *C. bacillaris*, *C. buxifolia*, *C. Fiancheti*, *C. Irigida*, *C. horizontalis*, *C. integerrima*, *C. microphylla*, *C. multillora*, *C. panosa*, *C. thymaefolia*, *Exochorda Alberti*, *Kerria japonica*, *Neviusia alahanensis*, *Pygeum africanum*, *P. latilolium*, *P. parvillorum*, *Spiraea Aruncus*, *S. japonica*, *S. Kneillii*, *S. Lindleyana*, *S. prunifolia*, *S. sorbilolia*, *Rhodotypos kerrioides*, *Stranvaesia glaucescens*, *Indigofera galegoides*, *Vicia angustilolia*, *V. canadensis*, *V. hirsuta*, *V. macrocarpa*, *V. sativa*, *Corynocarpus laevigata*, *Schleicheria trijuga*, *Echinocarpus Sigun*, *Lucuma Bonplandia*, *f. mammosa*, *L. pomifera*, *Memecylon spec.*, *Ipomoea dissecta*, *L. sinuata*, *L. vitifolia*, *Gymnema latilolium*, *Sambucus nigra*, *Plectronia dicocca*, *Chardinia xeranthemoides*, *Xeranthemum annuum*, *X. cylindricum*.

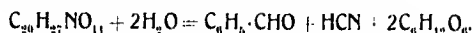
The presence of hydrocyanic acid is ascertained in the ordinary manner by means of the Prussian blue test. To a small amount of the distillate are added first a few drops of caustic soda solution and then a few drops of ferrous sulphate solution containing ferric salt. The mixture is once more thoroughly shaken and acidified with dilute hydrochloric acid. The precipitate of ferrous and ferric hydroxides is thus dissolved and in the presence of hydrocyanic acid, the characteristic blue precipitate of Prussian blue reveals itself. The reaction is so delicate that even the smallest traces of hydrocyanic acid can thus be detected.

For the rapid detection of hydrocyanic acid in a plant the observation of Mirande¹⁾ can be utilized. Under the influence of anaesthetics, such plants as contain hydrocyanic acid in complex combination, set free hydrogen cyanide, the presence of which can be detected by means of sodium picrate paper,²⁾ which is colored red by hydrogen cyanide.

For the quantitative determination of hydrogen cyanide see the chapter on "The examination of volatile oils".

Hydrogen cyanide does not occur as such in most plants but is contained in them in the form of a glucoside, of which amygdalin is the most common.

In plants amygdalin is accompanied by the ferment emulsin, which, in the presence of water, hydrolyses the glucoside to benzaldehyde, glucose and hydrogen cyanide:



In recent years much attention has been directed to amygdalin and its hydrolysis by means of emulsin. The rather complicated relationship cannot here be discussed. Suffice it to refer to the original literature on this subject.³⁾

In addition to amygdalin a number of other glucosides are known which upon hydrolysis yield hydrogen cyanide, viz.: corynocarpin, dhurrin, gynocardin, laurocerasin, linamarin (— phaseolunatin(?), lotusin, manihotoxin, prulaurasin, sambunigrin and vicianin.

Other nitriles occurring in volatile oils are those of phenylacetic acid, of phenylpropionic acid and of vinylacetic acid.

¹⁾ Compt. rend. 148 (1909), 140.

²⁾ Guignard, *Ibidem* 142 (1906), 552.

³⁾ Van Rijn, *Die Glycoside*. Berlin 1900; Walker, Journ. chem. Soc. 83 (1903), 472; Dakin, Journ. chem. Soc. 85 (1904), 1512; Bourquelot and Hérissé, Journ. de Pharm. et Chim. VI. 28 (1907), 5; Caldwell and Courtauld, Journ. chem. Soc. 91 (1907), 666, 671; Hérissé, Journ. de Pharm. et Chim. VI. 28 (1907), 194, 198; Arch. der Pharm. 245 (1907), 638, 641; Feist, *Ibidem* 246 (1908), 206, 509; Rosenthaler, *Ibidem* 365; Auld, Journ. chem. Soc. 83 (1908), 1251, 1276; Rosenthaler, Arch. der Pharm. 246 (1908), 710; Biochem. Zeitschr. 14 (1908), 238; 17 (1909), 257; Auld, Journ. chem. Soc. 85 (1909), 927; Feist, Arch. der Pharm. 247 (1909), 226, 542; Bourquelot, Journ. de Pharm. et Chim. VI. 29 (1909), 576; Tutin, Journ. chem. Soc. 85 (1909), 663; Walker and Kriebel, *Ibidem* 1369, 1437.

Phenylacetic acid nitrile, Benzyl cyanide, $C_6H_5CH_2CN$, according to A. W. Hofmann, is the principal constituent of the oil of *Tropæolum majus*,¹⁾ also of that of *Lepidium sativum*.²⁾ It is probably also contained in neroli oil.

Gadamer³⁾ has since shown that the observations of Hofmann with regard to *Tropæolum majus* are only conditionally true. When properly distilled, this plant yields benzyl mustard oil. The formation of benzyl cyanide is due to improper methods. (For further details see the oil of *Tropæolum majus*.)

Benzyl cyanide boils at 231 to 232° and at 18° has a specific gravity of 1.0146. When hydrolysed it yields phenylacetic acid, m. p. 77°.

Phenylpropionic acid nitrile, $C_6H_5CH_2CH_2CN$, is the principal constituent of water cress oil (*Nasturtium officinale*).⁴⁾ It boils at 261° and when acted upon by alkali is converted into phenylpropionic acid which melts at 47°.

Vinylacetic acid (Crotonic acid) nitrile, Allyl cyanide, $CH_2=CH\cdot CH_2CN$, traces of which are always found in mustard oil, can be obtained in larger amounts by careless distillation as decomposition product from allyl isothiocyanide. In as much as allyl cyanide is light ($d_{12.5} 0.835$), the presence of larger amounts of this substance would be revealed by a depression of the specific gravity of the mustard oil.

NITRO COMPOUNDS.

Nitrobenzene.



This compound, also known as oil of mirbane, which is prepared in large quantities, principally for the dye stuff industry, is also used in perfumery as a cheap substitute for oil of bitter

¹⁾ Berl. Berichte 7 (1874), 518.

²⁾ *Ibidem* 1293.

³⁾ Arch. der Pharm. 297 (1899), 111.

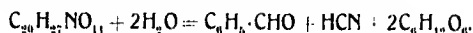
⁴⁾ A. W. Hofmann, *loc. cit.* 520.

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hot water or alcohol with a dark green color. The first of these two tests is the more delicate one.

Nitrobenzene is a strong poison. Cases are known when 20, or even 7 to 8 drops have proven fatal.¹⁾ Contact of nitrobenzene with the skin can also prove dangerous.

Artificial musk.

Natural musk owes its odor to a ketone, muscone, which is contained in the natural product to the extent of from 0.5 to 2%. As to its chemical composition only this much is known that either the formula $C_{15}H_{26}O$ or $C_{16}H_{28}O$ applies to it.²⁾ Muscone is a dark, colorless oil, which is but sparingly soluble in water, soluble in alcohol in all proportions. It has a strong, very agreeable, pure musk odor, which, in a concentrated condition, reminds of the fragrance of dried pine needles. In great dilution it is particularly agreeable. Like ionone it possesses the property to fatigue the nerves very readily. Hence it is possible to recognize the musk odor of the muscone for a short time only. It boils at 142 to 143° (2 mm.) and at 327 to 330° (752 mm.). Under the latter conditions partial decomposition appears to take place. Of muscone derivatives there are known the oxime, which crystallizes in needles that melt at 46°, and the semicarbazone, which crystallizes from alcohol in fine, white prisms that melt at 133 to 134°. Both compounds are odorless. From the semicarbazone the muscone can be liberated by means of dilute sulphuric acid.

The so-called artificial musk, however, is something very different. The only similarity between natural and so-called artificial musk is that of odor, such as is observed not infrequently, e. g. between nitrobenzene and bitter almond oil. In both instances the substitute is very different chemically from the original product and reproduces the odor only to a certain degree. At the present time there are found in the market a considerable number of "artificial musks". Most of these are highly nitrated tertiary butyl toluenes and tertiary butylxylenes or stand in close relation

¹⁾ Kobert, *Lehrbuch der Intoxikationen*, vol. II, p. 799. Stuttgart 1906.

²⁾ Walbaum, *Journ. f. prakt. Chem.* II, 73 (1906), 488; comp. also Report of Schimmel & Co. April 1906, 93.

to these nitrocompounds. Characteristic for these compounds is the tertiary butyl group. If other alkyl radicles take its place, the compounds resulting have either only a faint musk-like odor, or none at all.¹⁾ Those compounds containing three nitro groups are characterized by a strong musk-like odor. However, the strength of the musk odor is not interfered with if one of these nitro groups is replaced by a cyanogen or aldehyde group or by halogen or an acid radicle. With reference to these groups the artificial musks are distinguished as cyanide musk, aldehyde musk, halogen musk and ketone musk. The most important of these compounds are here described briefly.

Trinitro-tert.-butyltoluene, $C_6H_5 \cdot CH_3 \cdot C(CH_3)_3 \cdot (NO_2)_3$, is of special interest since it is the first musk-like smelling-substance which was placed upon the market as "Tonquinol" and "Muse Baur". It is obtained by condensation of isobutyl chloride and toluene with the aid of aluminium chloride and subsequent nitration of the butyl toluene. During the condensation a rearrangement of the isobutyl to the tertiary butyl group takes place. It is advantageous to purify the hydrocarbon carefully before nitrating it. Trinitrobutyl benzene crystallizes from alcohol in yellowish-white needles, which melt at 96 to 97°.

Trinitro-tert.-butylxylene, $C_6(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_3$, is prepared in like manner. It crystallizes in white needles that melt at 110°.

Trinitro-tert.-butylethylbenzene, $C_6H_5 \cdot C_2H_5 \cdot C(CH_3)_3 \cdot (NO_2)_3$, is readily soluble in alcohol and hence cannot readily be obtained in a crystalline condition.

Dinitro-tert.-butylxylene iodide, $C_6I(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_2$, results when tert.-butylxylene iodide is nitrated. It forms yellow crystals that melt at 105°.

Dinitro-tert.-butylxylene cyanide, $C_6(CH_3)_2CN \cdot C(CH_3)_3 \cdot (NO_2)_2$, cyanide musk. Prismatic crystals that melt at 110°.²⁾

¹⁾ Comp. Baur, Berl. Berichte 24 (1891), 2832; 31 (1898), 1344; Baur and Bischoff, *Ibidem* 32 (1899), 3647.

²⁾ Baur-Thurgau, Berl. Berichte 33 (1900), 2567.

Dinitro-tert.-butylxylene aldehyde, $C_6(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_2 \cdot CHO$, aldehyde musk, is soluble in alcohol and benzene and crystallizes from ligroin in plate-like, faintly yellowish crystals that melt at 112° .

Ketone musk is obtained by condensation of the corresponding acid chloride with tert.-butyltoluene or xylene in the presence of aluminium chloride and subsequent nitration of the condensation product. Baur¹⁾ has prepared the following representatives of this class.

Dinitroaceto-tert.-butyltoluene, $C_6H \cdot CH_3 \cdot C(CH_3)_3 \cdot (NO_2)_2 CO \cdot CH_3$, or methyl dinitrobutyltolyl ketone, broad needles that melts at 131° .

Dinitroaceto-tert.-butylxylene, $C_6(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_2 \cdot CO \cdot CH_3$, m. p. 136° ; soluble in alcohol, ether, benzene, &c., more difficultly in ligroin and 60 p. c. acetic acid.

Dinitrobutyryl-tert.-butylxylene, $C_6(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_2 \cdot CO \cdot C_4H_9$, is the butyryl ketone of dinitro-tert.-butylxylene, and melts at 128° .

Dinitrovaleryl-tert.-butylxylene, $C_6(CH_3)_2 \cdot C(CH_3)_3 \cdot (NO_2)_2 \cdot CO \cdot C_5H_9$, when crystallized from alcohol, is obtained as long, faintly yellowish needles that melt at 151° .

In addition to those enumerated above, other substances with a musk-like odor are to be found in the market. Moreover, mixtures of these are likewise found, for upon careful fractional crystallization compounds with different melting points are obtained.

Artificial musk is insoluble in water and, as a rule, is but difficultly soluble in alcohol. For the preparation of relatively concentrated solutions that are durable, cinnaeine and benzyl benzoate have been recommended. According to Koehler,²⁾ the latter solvent when gently heated dissolves as much as 20 p. c. of musk "Baur" and retains it in solution at $+10^\circ$. Neither does the addition of absolute alcohol cause precipitation. With

¹⁾ Baur-Thurgau, Berl. Berichte 31 (1898), 1344.

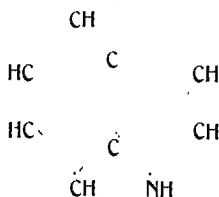
²⁾ Pharm. Ztg. 49 (1904), 1083.

cinnamein, Mann¹⁾ claims even to have obtained a 50 p. c. solution. According to Schimmel & Co.,²⁾ both solvents possess much the same solvent capacity, but benzyl benzoate appears to be a somewhat better solvent than cinnamein. Much, naturally, depends on the musk product dissolved.

Artificial musk is frequently adulterated with acetanilide. Formerly products of "Musk Baur" were placed upon the market which according to statements of the manufacturer contained up to 90 p. c. of antifebrine. Adulterations with cinnamic acid have also been observed. These added substances can be separated from the musk by means of hot water. Others are recognized by means of their solubility in alcohol in which solvent most artificial musk preparations are rather difficultly soluble. Antifebrine can be identified by means of the isonitrile and acetic acid reactions.

AMIDO AND IMINO DERIVATIVES.

Indol.



Indol has long been known to occur in the animal organism as a product of intestinal digestion. It has also been produced artificially for some time, but it is only recently that its occurrence in the vegetable kingdom has been established: first by Hesse³⁾ who found it in the oil obtained from jasmine flowers. Since then it has been found in neroli oil, also in the wood of

¹⁾ Seifensieder Ztg. 32 (1905), 112; Report of Schimmel & Co. April 1905, 117.

²⁾ Report of Schimmel & Co. April 1905, 118.

³⁾ Berl. Berichte 32 (1899), 2612.

the trunk of *Celtis reticulosa*.¹⁾ By means of color reactions its presence has likewise been established in the flowers of *Caladium* species, *Murraya exotica* and *Visnea Mocanera*.

Indol consists of shiny white laminæ, which, however, soon assume a dark color under the influence of light and air. They melt at 52°, b. p. 253 to 254° (corr.). It is readily soluble in hot water and is volatile with water vapor. The common commercial article has an exceedingly disagreeable, fecal odor. It is only when carefully purified that a product is obtained the odor of which is not decidedly disagreeable and which when properly diluted reveals a floral odor.

Solutions of oxalic acid²⁾ and of *p*-dimethylaminobenzaldehyde³⁾ are colored red by indol.

When an ethereal solution of indol is shaken with an aqueous alcoholic solution of sodium acid sulphite a hydrosulphonate results which crystallizes from methyl alcohol in white laminæ with a silky lustre.⁴⁾

For the isolation of indol, the picrate, crystallizing in long, red, shiny needles, is best suited. For the identification and quantitative determination of indol, Hesse⁵⁾ gives the following directions:

To the crude floral oil about 10 p. c. of picric acid are added. The mixture is heated to from 50 to 60° until the precipitate, first formed on the addition of the picric acid, is dissolved. To the cooled solution, from which an abundant precipitate of indol picrate has separated, a large excess of petroleum ether is added. The crystalline precipitate, consisting of indol picrate and the larger amount of uncombined picric acid, and which is colored more or less red in accordance with its indol picrate content, is

¹⁾ Herter, Journ. biol. Chem. 5 (1909), 489. According to Apotheker Ztg. 24 (1909), 885.

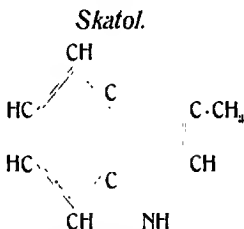
²⁾ Borzi, Rendiconti della R. Accad. dei Lincei 13 (1904), 372; Verschaffelt, Rec. trav. bot. Néerland. 1 (1904). Comp. also Report of Schimmel & Co. October 1905, 123.

³⁾ Wechuizen, Pharm. Weekblad 45 (1908), 1325; Steensma, Zeitschr. f. physiol. Chem. 47 (1906), 15; Gautier and Noyer, Compt. rend. Soc. biol. December 19th 1908; abstract in Bull. Soc. chim. IV. 5 (1909), 256. Comp. also Report of Schimmel & Co. April 1909, 140 and October 1909, 213.

⁴⁾ Hesse, loc. cit. 2615.

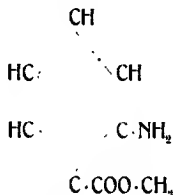
⁵⁾ Loc. cit. 2612.

removed by filtration and repeatedly washed with petroleum ether. The crystals thus purified are dissolved in ammonia or soda solution with the aid of gentle heat. Upon cooling the solution is shaken out with ether, and the ethereal residue distilled with water vapor. Thus the total indol of the floral oil is obtained in an almost pure state.



Skatol, *p*-methylindol, has thus far been found in civet and in the wood of *Celtis reticulosa*, also in a wood¹⁾ obtained from German East Africa. It crystallizes in white laminæ which melt at 95° and boil at 265 to 266° and which possess a strong fecal odor. The hydrochloride, $2\text{C}_8\text{H}_7\text{N} \cdot \text{HCl}$, melts at 167 to 168°. The picrate crystallizes from benzene in dark red, shiny needles, m. p. 172 to 173°.²⁾ The solution of *p*-dimethylaminobenzaldehyde is colored blue by skatol.³⁾ Like indol, skatol is used in the preparation of artificial floral perfumes.

Anthranilic acid methyl ester.



¹⁾ Report of Schimmel & Co. April 1903, 79.

²⁾ Observations made in the laboratory of Schimmel & Co.

³⁾ Weehuizen, Pharm. Weekblad 45 (1908), 1325; Steensma, Zeitschr. f. physiol. Chem. 47 (1906), 25; Gautier and Noyer, Compt. rend. Soc. biol. December 19th 1908; abstr. in Bull. Soc. chim. IV, 5 (1909), 256. Comp. also Report of Schimmel & Co. April 1909, 140; October 1909, 213.

Among the basic constituents of volatile oils the methyl ester of anthranilic acid should be mentioned. It was discovered in 1895 by Walbaum in neroli oil and has since been found in the oils of tuberose, champaca flowers (?), ylang-ylang, Spanish orange blossoms, sweet orange rind, West Indian lime (?), bergamot leaves, jasmin flowers, and gardenia. Judging from the odor, this ester is likewise contained in the flowers of *Lathyrus odorata*, *Robinia Pseudo-Acacia*, *Philadelphus Coronarius* and of several species of apples. Artificially it is readily obtained by passing hydrogen chloride into the methylalcoholic solution of anthranilic acid.

The methyl ester of anthranilic acid forms large crystals with numerous faces. Both crystals and solution, especially the alcoholic solution, reveal a beautiful fluorescence. Molten, it remains liquid for a long time, even at low temperature. The odor of the ester as such is not especially agreeable, but characteristic. Diluted, it reminds of the odor of orange blossoms. The constants of the compound isolated from neroli oil are:

Congealing point 24° ; m. p. 24 to 25° ; b. p. 132° (14 mm.); $d_{15} 1.168$ (in the supercooled condition).¹⁾

The ester is readily soluble in alcohol, ether and dilute inorganic acids, fairly readily in water and is volatile with water vapor.

Of its derivatives the following should be mentioned. The pierate crystallizes in yellow needles that melt at 103.5 to 104° .²⁾ The thiophenyl ketotetrahydroquinazoline results quantitatively when anthranilic acid methylester is heated with phenyl mustard oil to from 100 to 120° . This compound is readily soluble in caustic soda solution, very difficultly in alcohol. It melts above 300° but sublimes at 160 to 170° .

From volatile oils the ester can readily be separated by shaking with dilute sulphuric acid. The sulphate crystallizes out in the cold, can be purified by recrystallization from alcohol, and is decomposed by means of soda.³⁾

¹⁾ Walbaum, Journ. f. prakt. Chem. II. 59 (1899), 352.

²⁾ Freundler, Bull. Soc. chim. III. 81 (1904), 882. In the laboratory of Schimmel & Co. 105 to 106° were observed.

³⁾ Walbaum, Loc. cit.

Hesse and Zeitschel¹⁾ utilized the sulphate for the quantitative determination of the ester. They proceeded according to the following method:

About 25 g. of the oil to be examined are dissolved in twice or thrice the amount of dry ether. In a freezing mixture the temperature is reduced to at least 0°. Amidst constant stirring a solution of 1 vol. of concentrated sulphuric acid in 5 vols. of ether is added drop by drop until no further precipitate is produced. The precipitate is collected on a filter and washed with dry ether until it is odorless. It is then dissolved in water, if necessary with the aid of alcohol, and, without previous filtration,²⁾ is triturated with half normal caustic alkali. If for s grams of oil a ccm. of alkali are used, the percentage of ester in the oil equals

$$\frac{a \cdot 3,775}{s}$$

To the solution an excess of half normal alkali is now added and the mixture heated on a water bath for half an hour. The amount of alkali not used for saponification is titrated back with half normal sulphuric acid. The percentage of ester is computed according to the following formula:

$$\frac{b \cdot 7,55}{s}$$

in which b represents the amount of half normal alkali used for saponification. a should be again as large as b .

This method not only determines anthranilic acid methyl ester, but other basic substances as well (methylantranilic acid methyl ester). In order to avoid this, E. Erdmann³⁾ has suggested another method in which he utilizes the property of the ester as primary base to form azodyes. The ester is shaken out of the oil with either dilute sulphuric or dilute hydrochloric acid; the acid solution is diazotized with a 5 p. c. solution of sodium nitrite, and titrated with an alkaline solution of β -naphthol (0,5 g. β -naphthol in a solution of 0,5 g. of caustic soda and 15 g. sodium carbonate in 150 ccm. of water). The insoluble dyestuff

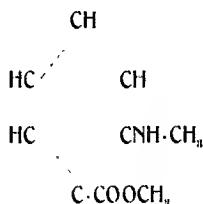
¹⁾ Berl. Berichte 34 (1901), 296.

²⁾ Hesse and Zeitschel, Journ. f. prakt. Chem. II. 61 (1901), 246, footnote.

³⁾ Berl. Berichte 35 (1902), 24.

is precipitated and the end of the reaction ascertained by testing a drop removed from time to time. According to Hesse and Zeitschel,¹⁾ the method of Erdmann suffers from the fact that the isolation of the ester is not a quantitative one. In order to obtain satisfactory results the ester should be isolated as sulphate as described above. For the rest either the one or the other method can be followed. If anthranilic acid methyl ester and methylanthranilic acid methyl ester are to be determined side by side it is advisable to combine both methods.

Methylanthranilic acid methyl ester.



Methylanthranilic acid methyl ester occurs in mandarin oil, also in mandarin leaf oil and possibly also in oil of ruc. Like the anthranilic acid methyl ester, it shows a blue fluorescence, as such as well as in solution. The constants of the ester isolated from mandarin oil are as follows:

M. p. 18,5 to 19,5 ; b. p. 130 to 131 (13 mm.); d_{15}^4 1,120.²⁾

In connection with a synthetic product containing 98 p. c. of ester, Schimmel & Co. observed the following constants:

Congezing point 17,8°; m. p. 18 ; d_{20}^4 1,1238; n_D^{20} 1,57963; soluble in 10 vol. of 70 p. c. and in 3 vol. of 80 p. c. alcohol.

For further characterization the saponification products can be utilized. Methylanthranilic acid crystallizes from alcohol in white prisms which melt at 179° and which reveal a blue fluorescence in solution.

¹⁾ Berl. Berichte 35 (1902), 2355.

²⁾ Walbaum, Journ. f. prakt. Chem. II. 62 (1900), 136.

SULPHIDES.

Sulphuretted hydrogen, H_2S , is frequently observed during the distillation of seeds, e. g. anise and particularly of caraway. Small amounts of *carbon disulphide*, CS_2 , are contained in the oil of black mustard. Both products presumably result as products of decomposition.

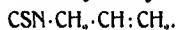
Dimethyl sulphide, $(CH_3)_2S$, b. p. 37° , has been found in American peppermint oil, also in Réunion and African oils of geranium.¹⁾ Traces of a *mercaptan* have been found in the oil of *Allium ursinum*, whereas the bulk of this oil consists of *vinyl sulphide*, $(C_2H_5)_2S$, (b. p. 101° ; $d_{20} 0.9125$) and its higher sulphides. Other unsaturated sulphides and polysulphides, among them presumably *allyl disulphide*, $(C_3H_5)_2S_2$, and *allylpropyl disulphide*, $C_3H_5 \cdot C_3H_7 \cdot S_2$, occur together with other sulphur compounds in the oils of garlic, onion and asafetida.

All of these compounds are characterized by a most disagreeable, penetrating odor. In the plants they are said to be contained in part, in combination as glucosides.

In this connection attention should be directed to Hartwich's²⁾ list of plants in which the presence of sulphur-containing volatile oils has been demonstrated or inferred because of their odor.

MUSTARD OILS.

The esters of *isothiocyanic acid*, characterized by their penetrating odor, and commonly known as mustard oils, constitute a special group of sulphur compounds. Their typical representative is the common allyl mustard oil.

Isothiocyanallyl.

Isothiocyanallyl, allyl mustard oil or commonly mustard oil, constitutes the bulk of the volatile oil of mustard. It has also been obtained from the following plants: *Alliaria officinalis*, *Capsella Bursa pastoris*, species of *Cardamine* and *Sisymbrium*, *Cochlearia Armoracia* and *Thlaspi arvense*.

¹⁾ Report of Schimmel & Co. April 1901, 55.

²⁾ Apotheker Ztg. 17 (1902), 339.

Neither in the mustard seed nor in the other plants mentioned does the mustard oil occur as such but in the form of a glucoside known as sinigrin (myronate of potassium), which in the presence of the ferment myrosin and water, is hydrolized to mustard oil, *d*-glucose and potassium acid sulphate:



However, side reactions also take place which account for the presence of cyanallyl and carbon disulphide, two substances that are never completely wanting in natural mustard oil.

Above 70° myrosin is decomposed and becomes inactive as ferment. At a temperature of 0° traces of rhodan allyl, CNSC_3H_5 ,¹⁾ isomeric with allyl mustard oil, are also formed. Of interest is also the observation made by Guignard²⁾ that mustard oil is set free when the plants are subjected to the vapors of mercury, carbon disulphide or anæsthetics.

Chemically, mustard oil is obtained by the distillation of allyliodide or allylbromide with an alcoholic solution of potassium rhodanate, or by the dry distillation of this salt with the equivalent amount of a salt of allylsulphuric acid. Under the influence of the heat an inversion of this cyanate or rhodanate group to the isothiocyanate group takes place.

Isithiocyan allyl is a colorless oil which gradually turns yellow. It is optically inactive and possesses a very penetrating odor causing the flow of tears. Applied to the skin, it produces a burning sensation and causes blistering. The vapors are particularly harmful to the lungs. It is soluble in 8 vol. of 70 p. c. alcohol and is miscible in all proportions with 90 p. c. alcohol, likewise with ether, amyl alcohol, chloroform, benzene and petroleum ether. In water it is but sparingly soluble.

B. p. 150,7° (728,9 mm.); $d_{40,5}$ 1,0173.³⁾

According to observations made on technical products in the laboratory of Schimmel & Co., synthetic mustard oil possesses the following properties:

B. p. (the bulk of the oil) 151 to 153 (760 mm.), 30,2° (5 mm.); $d_{15,5}$ 1,020 to 1,025; $n_{D,20}$ 1,527 to 1,530.

¹⁾ E. Schmidt, Berl. Berichte 10 (1877), 187.

²⁾ Compt. rend. 149 (1909), 91.

³⁾ Kopp, Liebig's Annalen 98 (1856), 375.

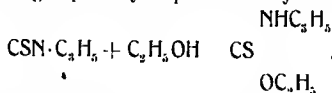
When small amounts of mustard oil are mixed with twice their volume of concentrated sulphuric acid a violent evolution of carbon oxysulphide¹⁾ and sulphur dioxide²⁾ takes place and allylamine sulphate, $C_3H_5NH_2 \cdot H_2SO_4$, is formed. This remains in the test tube as a clear, slightly colored liquid, or occasionally congeals. As an unsaturated compound, mustard oil adds bromine with the formation of an oily dibromide, $CSN \cdot C_3H_5Br_2$, which is volatile with water vapors.

For the identification of mustard oil, allylthiourea (thiosin-
 NHC_3H_5
 aminc), CS , is particularly suited. It crystallizes in
 NH_2

rhombic prisms that melt at 74° , has a faint leek-like odor and taste, and is readily soluble in water, alcohol and ether. The compound results when an excess of ammonia and some alcohol are added to mustard oil. The reaction is accelerated by gentle heat. For the quantitative determination of mustard oil, see the chapter on "The examination of volatile oils".

Exposed to light, mustard oil gradually acquires a reddish-brown color and the bottle is coated with a dirty orange-yellow film containing carbon, nitrogen, hydrogen and sulphur.

Prolonged contact with water or with heavy metals, such as copper, silver, tin, mercury, causes decomposition of the mustard oil with formation of cyanallyl. The metals combine with the sulphur to sulphides. Ethyl alcohol also gradually causes a change forming a partially sulphuretted allylurethane:



It is because of this reaction that spirit of mustard gradually loses its therapeutic action.

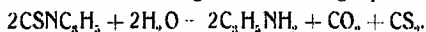
The source of the carbon disulphide always found in mustard oil, even in the artificial product, has not yet been definitely ascertained. Experiments have shown³⁾ that, whereas boiling of mustard oil with water in a flask connected with a reflux condenser for an hour does not yield carbon disulphide, appreciable amounts

¹⁾ A. W. Hofmann, Berl. Berichte 1 (1868), 182.

²⁾ Flückiger, Arch. der Pharm. 196 (1871), 214.

³⁾ Gadamer, Arch. der Pharm. 25 (1897), 53.

of this substance, together with carbon dioxide, are produced when mustard oil and water are heated in a sealed tube under pressure for several hours to a temperature of 100 to 105°. It may be assumed that in the nascent state mustard oil possesses a greater capacity for reaction and that under such conditions it reacts with water according to the following equation.



Carbon disulphide is also formed when mustard oil is allowed to remain in prolonged contact with water at ordinary temperature.

Of other mustard oils the following may be briefly described in this connection.

Isothiocyanpropenyl, $\text{CSN}\cdot\text{CH}:\text{CH}\cdot\text{CH}_3$. According to Pomeranz,¹⁾ traces of this occur in mustard oils. He assumes to have established its presence in artificial mustard oil by having identified acetic acid as well as formic acid among the oxidation products.

Secondary butyl mustard oil, $\text{CSN}\cdot\text{CH}(\text{CH}_3)\cdot\text{CH}_2\cdot\text{CH}_3$, the isothiocyanate of secondary butyl alcohol, is the principal constituent of the oil of *Cochlearia officinalis*, and has been isolated from the oil of the herb *Cardamine amara*. This mustard oil likewise does not occur as such, but in the form of a glucoside known as glucocochlearin.²⁾

Secondary butyl mustard oil is an optically active, colorless liquid possessing the characteristic odor of cochlearia oil.

B. p. 159.5°; $d_{15} 0.944$.³⁾

Heated with ammonia to 100° it yields a thiourea which melts at 135 to 136° and which is optically active. In alcoholic solution, the oil gradually loses its original pungency. Presumably a partially sulphuretted urea is formed as in the case of allyl mustard oil.

The commercial "artificial oil of spoon wort" is isobutyl mustard oil, $\text{CSN}\cdot\text{CH}_2\cdot\text{CH}(\text{CH}_3)_2$, hence not identical with the natural product. It boils at 162° and yields a thiourea melting at 93.5°.

¹⁾ Liebig's Annalen 351 (1907), 354.

²⁾ Ter Meulen, Recueil des trav. chim. des P.-B. 24 (1905), 444. According to Chem. Zentralbl. 1906, II. 1255.

³⁾ A. W. Hofmann, Berl. Berichte 7 (1874), 513.

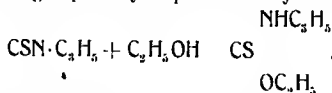
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¹⁾ A. W. Hofmann, Berl. Berichte 1 (1868), 182.

²⁾ Flückiger, Arch. der Pharm. 196 (1871), 214.

³⁾ Gadamer, Arch. der Pharm. 25 (1897), 53.

THE EXAMINATION OF
VOLATILE OILS.





As the various oils are fully described in the second vol. of this treatise, it will be expedient, in order to avoid repetition, to discuss briefly in a special chapter the general methods used in their investigation and the most common adulterants met with.

The practice of adulteration of the volatile oils, which is probably as old as the manufacture itself, had in the beginning a certain justification, as with the incomplete technical equipment of the early times the addition of fatty oils, turpentine oil, or alcohol was often necessary in order to extract from the plants their odorous principle. Later, when the preparation of the pure oils was already known, the practice of making these additions was still retained.

Even forty years ago, it was customary to distill coriander with the addition of orange oil and to put the distillate on the market as coriander oil. Since pure coriander oil can now be prepared without difficulty, the product obtained by using orange oil, as it is found now and then even at the present time, must be considered as adulterated and if the foreign ingredient is not made known, its sale is a fraud.

The adulteration need not always be by the addition of a less valuable body, it sometimes consists in that the more valuable constituent of the oil has been partially removed. The effect is the same, whether from a caraway oil of the specific gravity 0,910 so much carvone be removed that an oil of the specific gravity 0,890 remains behind, or whether the same result is attained by the addition of limonene to the same oil.

Although the adulterations themselves mostly find a sufficient explanation in the profitableness and the pecuniary advantage to the adulterator, it cannot, however, be denied, that often the ignorance of the consumer, and above all the desire to buy as

cheaply as possible, is the cause of the spurious composition of many an oil. More than once the producer may have been induced to adulterate, because he found no buyers for his pure products at a reasonable price, while his adulterating competitor was able to do a lucrative business at lower prices.

The main reason for the extensive adulteration to which volatile oils have been subjected at times, is to be sought in the fact that the detection of adulterants was very difficult and often entirely impossible.

Owing to the development of the chemistry of the terpenes and their derivatives, great progress has been made during the last twenty five years in the detection of adulterations. Knowing the composition of not a small number of volatile oils, it has become possible not only to distinguish between a pure and an adulterated oil, but also to judge the quality of these oils. This is effected by estimating the amount of the principal, or the most important constituent. In lavender oil, bergamot oil, petit-grain oil and others, the amount of esters present are therefore determined; in thyme oil, clove oil, pimenta oil, bay oil, and Cretian origanum oil the amount of phenols are estimated; in cassia oil and lemongrass oil the amount of aldehyde; in earaway oil the amount of carvone. The assay of santalwood oil shows how much santalol, that of palmarosa oil, how much geraniol is contained in the oil. The quality of the oils named finds numerical expression in the percentage strength of the active constituents such as esters, phenols, aldehydes, ketones and alcohols.

In a second class of oils, whose composition is likewise sufficiently known, an assay is not yet possible. The reason for this is twofold: first the value of the oil depends not upon a single constituent but upon the blending of the properties of several; and secondly the chemical methods of investigation are not sufficiently developed.

With these oils, the examination is restricted as a rule to the determination of the normal composition of the oil and the absence of commonly used adulterants. Such oils are lemon oil, orange oil, rosemary oil and spike oil, which should be tested particularly for turpentine oil.

The incomplete knowledge of the composition and the defectiveness of the methods of testing most of the oils, do not at

present allow of an investigation resting on a rational chemical basis. With this class of oils the entire examination consists in determining the physical constants. As the average and limit values of specific gravity, optical rotation, solubility, &c., of the more common oils are well known through observations extending over many years, variations from these values call the attention of the investigator to adulterants.

Indeed, the physical behavior of an oil is in general very well suited to indicate rapidly the addition of foreign substances; the investigation of volatile oils should therefore begin with the determination of the physical properties, no matter whether the investigation be for practical or for scientific purposes. After this, the special methods are to be used, such as saponification, acetylation, aldehyde and phenol determinations, and finally, if it appears necessary, the tests for turpentine oil, fatty oil, alcohol or petroleum should be applied.

It is of course evident that when the practical value of an oil is to be considered, the examination as to its odor¹⁾ and

¹⁾ Attention may here be called to the interesting publications by H. Zwaardemaker: *Die Physiologie des Geruchs* (Leipzig 1895); *Die Riechkraft von Lösungen differenter Konzentration* (Arch. f. Anatomie u. Physiologie, Physiol. Abtlg. 1900, 415); *Die Kompensation von Geruchsempfindungen* (*Ibidem* 1900, 423); *Geruch* (Ergebnisse der Physiologie 1 (1902), 896); *Riechen und schmecken* (Arch. f. Anatomie u. Physiologie, Physiol. Abtlg. 1903, 120); Report of Schimmel & Co. October 1904, 107; *Präzisions-Olfaktometrie* (Arch. f. Laryngologie Bd. 15, Heft 2; Report of Schimmel & Co. October 1904, 105); *Geschmack* (Ergebnisse der Physiologie 2, 2 (1903), 699); *Eine bis jetzt unbekannt gebliebene Eigenschaft des Geruchssinnes* (Arch. f. Anatomie u. Physiologie, Physiol. Abtlg. 1904, 43); Report of Schimmel & Co. October 1904, 109); *Die Empfindung der Geruchlosigkeit* (Untersuchungen aus dem physiologischen Laboratorium 5. Reihe IV, II, 376; Report of Schimmel & Co. October 1904, 107); *Odorimetrie von prozentischen Lösungen und von Systemen im heterogenen Gleichgewicht* (Untersuchungen aus dem physiologischen Laboratorium 5. Reihe IV, II, 387; Report of Schimmel & Co. October 1904, 105); *Über die Proportionen der Geruchskompensation* (Arch. f. Anatomie u. Physiologie, Physiol. Abtlg. 1907, 59; Report of Schimmel & Co. April 1908, 173); *Die vektorielle Darstellung eines Systems von Geruchskompensationen* (Arch. f. Anatomie u. Physiologie 1908, 51; Report of Schimmel & Co. October 1908, 160). Comp. also E. Erdmann, *Über den Geruchssinn und die wichtigsten Riechstoffe* (Zeitschr. f. angew. Chem. 1900, 103) and J. van der Hoeven Leonhard, *Riechschärfe und Farbsinnabweichungen* (Die Umschau 12 (1908), 367; Report of Schimmel & Co. October 1908, 160).

taste must accompany the chemical and physical investigation, for these are the properties on account of which the volatile oils are used in the perfume and soap industries, in the manufacture of candies and liquors, and partly at least in medicine.

It is necessary, or at least greatly to be desired, to have for comparison a sample of a genuine, faultlessly distilled oil. A few drops each, of the genuine oil and of the oil to be tested, are put on a strip of filter paper, and compared by smelling alternately of both. This odor test is repeated after the larger part of the oil has volatilized, and in this manner readily volatile as well as more difficultly volatile foreign substances may be recognized.

It is possible, however, to give only a very imperfect expression in language of odor and taste perceptions; moreover, odor and taste are purely subjective and are also quite differently developed faculties in each individual. The perceptions made with the sense of odor and of taste do not admit of expression and comparison by means of figures like other observations. An adulteration may, therefore, be subjectively recognized, but cannot be objectively proven. A good sense of smell is in spite of this limitation of great value in the examination, as it often directs the investigation into the proper channel in the shortest time.

Poorly distilled oils, possessing an empyreumatic odor or "Blascngeruch", or oils carelessly kept but otherwise unadulterated are almost altogether recognized by the sense of smell, rarely by any other means of investigation.

DETERMINATION OF THE PHYSICAL PROPERTIES.

SPECIFIC GRAVITY.

On account of its ready determination the specific gravity is the most frequently taken and, therefore, the best known property of the volatile oils. Even concerning the rare and little investigated oils statements of their density are to be found.

Further, as the maximum and minimum values of the more commonly used oils are fixed, the determination of the specific gravity belongs to the most important and also most convenient means of investigation. The specific gravity of an oil is changeable within certain limits, and dependent, outside of age, on the manner of the distillation and also upon the source and the state of ripeness of the plant material used. The extent of this variation is so different in the individual oils that no general rules can be formulated. With normal bergamot oil, for instance, the specific gravity lies between 0,881 and 0,886. The difference between the highest and the lowest density, therefore, amounts in this case to only five places in the third decimal. As a rule, however, the limit values lie much further apart.

Most oils are lighter, some, however, heavier than water, especially those which contain larger amounts of oxygenated constituents of the aromatic series (e. g. wintergreen oil, clove oil, sassafras oil). The lowest specific gravity of all volatile oils is that of *Pinus Sabiniana* with 0,6962; the highest is that of wintergreen oil with 1,188.

The determination is conveniently performed with an hydrostatic balance according to Mohr or Westphal¹⁾, as the accuracy attained with this instrument, if rightly handled, is sufficient. The values obtained thereby are reliable to the third decimal. For the more accurate determination, or when only small quantities of an oil are at disposal, a pycnometer is used. The modifications of Sprengel (Fig. 66) and of Ostwald (Fig. 67) are especially to be recommended. For practical reasons it is expedient to mark

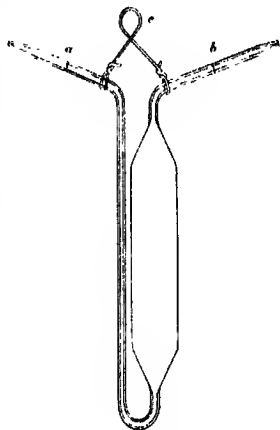


Fig. 66.

¹⁾ The hydrostatic balance with steel axes by F. Sartorius, Göttingen, may be especially recommended.

the capillaries at *a* and *b* and to bend these slightly upward as shown in the accompanying illustrations. The instrument is suspended from the balance by means of the platinum wire *c*. The capillaries can be sealed by means of the glass caps *d* and *e*. The pycnometer likewise yields more accurate results with viscid oils in which the thermometer body of the Mohr-Westphal balance does not move up and down with sufficient ease. For viscid oils

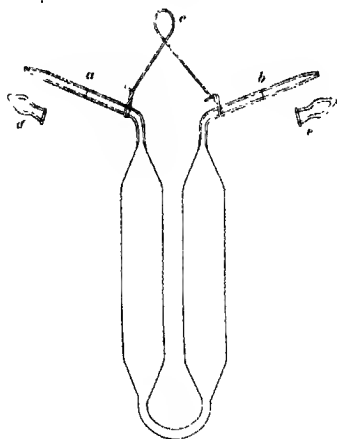


Fig. 67.

the capillaries should be relatively large otherwise the filling and emptying of the instrument is accompanied with difficulties. For the determination of the specific gravity, the weight of the completely dry instrument should be known, also its water value. For the determination of the latter, the pycnometer, previously filled with distilled water, is placed into a water bath of constant temperature (usually $+15^{\circ}\text{C.}$) for about a quarter of an hour or until it has assumed the temperature of the water bath. In the mean time distilled water is either added or withdrawn so as to bring the contents to the marks on the capillaries, when the weight is determined accurately. These two values, viz., P_1 (weight of the pycnometer) and P_2 (weight of the pycnometer plus water) are determined once and for all for a given instrument.

$P_2 - P_1$ is the water value W of the pycnometer. If the specific gravity of an oil is to be ascertained, the pycnometer is filled with the oil in question, the same conditions as to temperature being observed as before, and weighed. If the pycnometer filled with oil weighs P_2 , then the specific gravity of the oil is

$$s = \frac{P_2 - P_1}{W}.$$

In order to enable the convenient filling and evacuation of the instrument, a tube with glass ground connection with the capillary, as illustrated in fig. 68, is employed. In the case of viscid oils these operations are facilitated with the aid of gentle heat.

The specific gravity is naturally dependent on the temperature. For its determination $+15^\circ \text{C.}$ has been chosen as a matter of expediency. The water value is likewise determined at this temperature.¹⁾ The instruments used in Germany are calibrated in accordance with this rule, including the Mohr-Westphal balance. Only the specific gravity of such oils as are too viscid at 15°C. or congeal either entirely or in part, is taken at higher temperatures, however, with reference to water at 15° , so that the same instruments can be used for these determinations at higher temperatures.



Fig. 68.

Experiments have shown²⁾ that for the temperature of water at 15°C. the specific gravity of the volatile oils varies from 0,0007 to 0,0008 for each degree centigrade, i. e. on an average 0,00075. With the aid of this factor, the specific gravity of an oil can be recomputed for any temperature. If the temperature at which the specific gravity was determined was higher, 0,00075 should be added for each degree difference, if lower, the corresponding value should be deducted.

If, however, the specific gravities have been determined, not with reference to water at 15° but with reference to water at the same temperature at which the density of the oil was as-

¹⁾ Unless otherwise specified, the specific gravities recorded in this book are for the temperature of $+15^\circ \text{C.}$ with reference to water at 15° .

²⁾ Report of Schimmel & Co. October 1905, 87.

certained, corrections can be made in like manner. According to Schreiner and Downer¹⁾ the correction factor for observations between 15 and 25° is 0.00064 for each degree.

As a matter of course such computed values can be regarded as approximations only. For accurate data the specific gravity should be actually determined at the temperature in question.

OPTICAL ROTATION.

The optical rotation is such a characteristic property of most of the volatile oils that its determination should never be omitted in an examination. Especially adapted for this purpose is the half-shadow polariscope according to Lippich²⁾ with polarisor in two parts. The best division of the circle for the purpose in question is that into degrees and minutes in such a way that the numbers on each side of the zero point run up to 180°. If the dark color of the oil does not allow of making the observation in a 100 mm. tube, which is the one usually employed, one of 50 or even 20 mm. may be used and the values obtained are multiplied by 2 and 5 respectively. If the color permits, inactive substances are observed in 200 mm. tubes in order that slight deviations may be detected. When no special mention is made of the temperature, room temperature is to be understood. In general it is not necessary, although desirable, to make the observation at a fixed temperature, as the natural variations in the rotation of an oil are usually greater than the differences due to a variation in temperature of several degrees. Exceptions to this are the oils of lemon and orange, the rotation of which is relatively strongly influenced by even small changes in temperature. It is necessary, in order to get comparable figures, to determine the rotation of these two oils at +20° or else to reduce the result to this temperature by calculation. The details of this will be found in the description of these oils in the special part.

¹⁾ Pharmaceutical Archives 4 (1901), 165. Comp. also Report of Schimmel & Co. April 1906, 71.

²⁾ With regard to the manipulation of the polariscope the reader is referred to the wellknown work by H. Landolt, *Das optische Drehungsvermögen organischer Substanzen*, II. ed., Braunschweig, 1898.

In the following, α_p is the observed angle of rotation in a 100 mm. tube with sodium light, and $[\alpha]_D$ is the specific rotation as calculated by the formula

$$[\alpha]_D = \frac{\alpha}{l \cdot d}$$

where α is the observed angle of rotation, l the length of the tube in decimeters and d the specific gravity of the liquid.

Solid substances are dissolved in an optically inactive liquid. The computation is effected according to one of two formulas, depending as to how the concentration is expressed: either by c , *i. e.* the number of grams of substance in 100 cc. of solution, or by percentage, *i. e.* the number of grams of active substance in 100 g. of solution. In the latter instance the specific gravity (d) of the solution must be known. If the solution deviates the ray of polarized light α degrees the specific angle of rotation follows from the following equation:

$$[\alpha]_D = \frac{100 \cdot \alpha}{l \cdot c} = \frac{100 \cdot \alpha}{l \cdot p \cdot d}$$

The angle of rotation thus ascertained is not strictly constant for most substances, but varies with the nature of the solvent, the concentration, and the temperature.¹⁾ Consequently it is necessary to record the conditions observed with the specific angle of rotation, *e. g.* $[\alpha]_{D_{20}} = 10^\circ$ in a 43.5 p. c. alcoholic solution.

REFRACTION.

The determination of the index of refraction n_D has been recommended repeatedly for the examination of the volatile oils. As is well known, certain relations exist between chemical constitution and refraction and in many cases conclusions as to the position and number of double bonds may be drawn from the molecular refraction. Chemical individuals carefully purified are, however, necessary in order to obtain useful results. As the refractive coefficients of the constituents of the volatile oils are on the whole only slightly different from each other, they are not so well suited for the detection of adulterations as are

¹⁾ As to the influence of the solvent on the angle of rotation compare Landolt, *Liebig's Annalen* 149 (1877), 311; Rimbach, *Zeitschr. f. physik. Chem.* 9 (1892), 701.

other methods of examination. The addition of turpentine oil, for instance, influences the refraction of lemon oil only slightly, but changes the rotation to a marked degree.¹⁾

In isolated cases, the index of refraction may nevertheless serve as a valuable supplement to the other constants and should, therefore, not be omitted on principle. Hence, in the discussion of the individual oils, reference will frequently be made to these constants and limit values will be given.

For this purpose the Pulfrich refractometer can be especially recommended. The observations are made with sodium light.

The variations in the index of refraction due to differences in temperature vary somewhat for different oils and average about 0.00035²⁾ for each degree of temperature. These variations are noteworthy in as much as the indices of refraction of the different volatile oils vary but little among themselves, viz., from 1.43 (oil of rue and cognac oil) and 1.61 (cassia oil). Great care with reference to temperature should, therefore, be exercised in the determination. As a rule, the observations are made at 20°. Only in such cases, as that of oil of rose, in which the consistence of the oil does not admit of the determination, a higher temperature is chosen. Hence $n_{1,20}$ signifies the index of refraction for sodium light at 20° C. A recomputation with the aid of the above mentioned factor yields approximate values only and is not admissible for accurate values.

As a result of the formation of oxidation and polymerization products, the index of refraction increases with age. An exception is found in the behavior of anethol.³⁾

Mention should yet be made of the specific and molecular index of refraction although they apply to chemical individuals only.

The specific index of refraction finds expression in the formula

$$\frac{n_s - 1}{n_s + 2} \cdot \frac{1}{d}$$

in which d is the specific gravity determined at the same temperature at which the index of refraction is determined. The

¹⁾ Report of Schimmel & Co. October 1893, 55.

²⁾ According to observations by Schimmel & Co.

³⁾ Comp. Report of Schimmel & Co. October 1904, 42.

⁴⁾ The above formula has been proposed by Lorenz and Lorentz. The older formula by Gladstone, viz. $\frac{n}{d}$ does not always yield constant values.

molecular index of refraction or the molecular refraction is obtained by multiplying the specific index of refraction with the molecular weight.

CONGEALING POINT.

With certain oils, especially anise, star anise, fennel and rue oils, the congealing point affords a good means for judging the quality. With the first three oils a high congealing point shows a large content of anethol, with rue oil one of methyl nonyl ketone.

In isolated cases the melting point has been recommended for the determination of volatile oils. However, it is little suited to this end, since the volatile oils are not individual compounds but mixtures which reveal no sharp melting point throughout the entire mixture, but soften at first and then gradually change to a clear liquid. As a result no fixed melting point can be observed, but a temperature interval between which the oil melts. Contrasted with the melting point, the congealing point can be clearly and sharply observed.

The determination of the congealing point can be very well performed with Beckmann's well-known apparatus for the determination of the molecular weight by the lowering of the freezing point. A few slight changes make it especially suited for this purpose. They consist principally in doing away with the cork connections which hinder the free inspection of the mercury thread of the thermometer. The laboratory of Schimmel & Co.¹⁾ has the form shown in fig. 69. The battery jar *A* serves as the receptacle for the cooling liquid or freezing mixture. The glass tube *B* hanging in the metal cover serves as an air jacket for the freezing tube *C* and prevents the premature congealing of the oil to be tested. The freezing



Fig. 69.

^{1/2} der wirklichen Größe.

¹⁾ Report of Schimmel & Co. October 1898, 43.

tube *C* is wider at the top and becomes narrower at the place where it rests on the edge of the tube *B*. In order to retain *C* in fixed position, three glass projections are fastened on the inside of the tube *B*, about 5 cm. below its upper edge. The thermometer, which is graduated into half degrees is held in position in a metal plate by three springs which allow of sliding the thermometer up or down.

To carry out the test, the battery jar is filled with either water and pieces of ice or with chopped ice, according to the reduction of temperature desired. Only occasionally it is necessary to employ a freezing mixture of ice and salt. Then pour into the freezing tube so much of the oil to be tested that it stands at a height of about 5 cm. in the tube and bring the thermometer, which must not touch the sides of the tube at any place, into the liquid. During the cooling the undercooled oil is to be protected from disturbances, which would produce a premature congealation.¹⁾ When the oil has been sufficiently undercooled, crystallization is to be induced by rubbing and scratching the thermometer against the sides of the tube. If this proceeding should not prove successful a small crystal of congealed oil or some solid anethol or methyl nonyl ketone is brought into the liquid, when congealation will take place with liberation of heat. The solidification is hastened by continued stirring with the thermometer, the mercury thread of which rises rapidly and finally reaches a maximum which is called the congealing point of the oil.

The oil should be sufficiently undercooled, otherwise the congealation will proceed too slowly thus rendering the observation more difficult. Again, the oils should not be undercooled too much, otherwise the results observed will be too low. Practically useful results are obtained when the oils are undercooled about 5°. It is desirable always to work under like conditions in order that the various qualities of the respective oils may be judged from a common view point. Schimmel & Co. subcool as follows:

| | | | |
|---------------|------------|------------|-----------|
| Anethol | to -- 16 , | Anise oil | to + 12°. |
| Staranise oil | to + 10 , | Fennel oil | to + 3 . |

¹⁾ A premature congealation often takes place when the oil has not been filtered clear, as suspended dust particles may give rise to congealation.

In certain cases it is desirable to record the temperature to which an oil was subcooled.

It should be mentioned that reference is had to the congealing temperature of oil of rose. This refers to the temperature at which the paraffin crystals are formed when the oil is slowly cooled.

BEHAVIOR ON BOILING AND FRACTIONAL DISTILLATION.

Inasmuch as the volatile oils are mixtures of substances with different boiling points, it is improper to speak, as is so often done, of the boiling point of a volatile oil. It is more correct to speak of a boiling temperature, by which is meant the temperature interval within the limits of

which the oil distills over in a single distillation from an ordinary distilling flask (fig. 70) without the application of a fractionating arrangement. It

is of the greatest importance that the entire column of the mercury be surrounded by the vapors of the distilling oil, a circumstance that is often ignored and leads to erroneous results. The thermometer should be adjusted in such a manner that the respective boiling point is placed slightly above the exit tube of the distilling flask. Care, however, should be exercised that the mercury bulb of the thermometer does not project into the body of the flask, much less into the liquid. In order to avoid this, thermometers with shortened scales are preferably used.

Of great importance is also the rate of distillation which is best regulated so that 40 or at most 60 drops are collected per minute. If the distillation is conducted too rapidly and if the exit tube is not large enough the vapors are choked causing an increase in pressure and a corresponding rise in temperature. The consequence is this that the observed boiling point is too high.

In order to avoid bumping, small pieces of pumice, tiling or oil of talcum are added to the liquid.

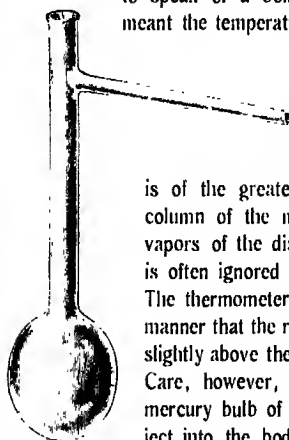


Fig. 70

Whereas the determination of the boiling point is of importance in the examination of chemical individuals, fractional distillation yields better results in the examination of volatile oils. The several fractions are collected separately, their amounts ascertained, and each fraction examined separately if necessary.

The observations recorded by different observers of the amounts of the same oil which distill over between certain limits of temperature, seldom agree, because the results are not only greatly influenced by the form of the distilling flask, but also by the rapidity of the distillation and the height

of the barometer. In the examination of certain fractions of individual oils it is therefore necessary, to use flasks of fixed dimensions and to observe a certain rapidity of distillation. For testing lemon

oil, rosemary oil and spike oil, Schimmel & Co. use distilling flasks according to Ladenburg of the dimensions given in fig. 71.¹⁾ From 50 ec. of the oils mentioned, 5 ec. are distilled over in such a manner that about 1 drop falls in a second, and the distillate tested in the polariscope, as will be described more in detail under the individual oils.

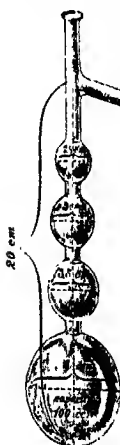


Fig. 71

When the different constituents are to be isolated from an oil, the fractional distillation must be repeated many times and preferably by employing one of the well known distilling columns. In order to avoid decomposition, it is best to distill the fractions boiling above 200° in vacuum. Oils containing esters must first be saponified, as the acids, which are easily split off by the boiling, disturb the fractionation and may act upon the other constituents of the oils.

SOLUBILITY.

The volatile oils are readily soluble in the ordinary solvents, such as alcohol, ether, chloroform, benzene, acetic ether, carbon

¹⁾ Report of Schimmel & Co. October 1898, 41.

disulphide, &c. Mention of this general property is not made in the description of the individual oils. A phenomenon which is sometimes considered as an incomplete solubility may be mentioned here. The turbidity noticed when certain oils are mixed with petroleum ether, paraffin oil¹⁾ or carbon disulphide may be caused by the small amount of water which the oils have retained from their preparation. The richer an oil is in oxygen, the more water it is capable of dissolving and the more cloudy does it become with petroleum ether.²⁾ The turbidity does not take place when the oil has been thoroughly dried with anhydrous sodium sulphate.

Although all oils are readily soluble in strong alcohol, only some of them are entirely soluble in dilute alcohol. For the last class this property becomes a practical and rapid means of examination. The presence of the difficultly soluble turpentine oil can, for instance, be readily shown in this manner in the oils soluble in 70 p. c.³⁾ alcohol. The solubility determination is very simple. Bring into a small graduated cylinder (fig. 72) 1 to 1 cc. of the oil to be tested and add small portions of the alcohol at a time until with vigorous shaking solution is effected. If an oil which is soluble under normal conditions does not dissolve, it is sometimes possible to draw conclusions as to the adulterant from the character of the turbidity and the separation of the insoluble part. Petroleum floats on the 70 p. c. alcohol, whereas a fatty oil settles in drops at the bottom.



Fig. 72.

For the examination of volatile oils, alcohol of different percentage strength is used. In the following table the strengths thus far employed are enumerated together with their specific gravities for 15° .⁴⁾

¹⁾ Cinnamic aldehyde is an exception to this rule. It is practically insoluble in petroleum ether and paraffin oil. Hence cassia oil and Ceylon cinnamon oil dissolve but incompletely in these solvents.

²⁾ When an oil rich in oxygen, such as bergamot oil, is mixed with one rich in terpenes, as turpentine oil or orange oil, the mixture becomes turbid due to the separation of water.

³⁾ The statements in this book always refer to volume percent.

⁴⁾ According to K. Windisch, *Tafeln zur Ermittlung des Alkoholgehaltes von Alkohol-Wassermischungen aus dem spezifischen Gewicht*. Berlin, 1893.

| | | | |
|----------------------|----------------------|----------------------|----------------------|
| 30 percent by volume | d_{15}^{15} 0,9656 | 69 percent by volume | d_{15}^{15} 0,8928 |
| 40 | 0,9521 | 70 | 0,8904 |
| 50 | 0,9347 | 80 | 0,8642 |
| 56 | 0,9226 | 82 | 0,8586 |
| 60 | 0,9139 | 85 | 0,8499 |
| 62 | 0,9094 | 90 | 0,8343 |
| 65 | 0,9025 | 95 | 0,8165 |
| 68 | 0,8953 | 98 | 0,8040 |

In order to avoid the necessity of keeping on hand alcohol of different percentage strength, Dowdard¹⁾ has recommended a method which is worth mentioning though it has not established itself. 5 cc. of an oil are dissolved in 10 cc. of absolute alcohol (d_{15}^{15} 0,799) and the solution diluted with water from a burette until the solution becomes permanently turbid. By multiplying the number of cc. of water by 100 the "solubility value" is obtained. In connection with bergamot oil, Dowdard determined values between 220 and 290.

The same author suggests the determination of the *viscosity*²⁾ as a means for examining volatile oils. For the volatile oils, however, this method has never attained practical significance.

CHEMICAL METHODS OF TESTING.

The rational examination of a volatile oil in a chemical manner is possible only if its composition or at least its main constituents are known. The chemical investigation must be directed as much as possible toward the isolation and quantitative estimation of the constituents recognized as being the most valuable. The methods of testing must, therefore, conform to the analysis of the oil. If this really self-evident supposition had been generally recognized earlier, those methods of investigation, which are designated as quantitative reactions, as for instance the iodine absorption, or Maumené's sulphuric acid test, which had given good results with the fatty oils, would not have been applied offhand to the volatile oils.

¹⁾ Chemist and Druggist 53 (1898), 749.

²⁾ Chemist and Druggist 57 (1900), 169. Report of Schimmel & Co. April 1901, 31

The fatty oils are a group of chemically closely related bodies; they are glycerides of the fatty and oleic acid series. The constituents of the volatile oils, however, recruit themselves from the greatest variety of classes of bodies. Among them may be found terpenes, sesquiterpenes, paraffins, alcohols, aldehydes, ketones, phenols, ethers, oxides and esters. It should be no matter for surprise, therefore, that the methods of testing which are useful with the fatty oils, fail utterly with the volatile oils. Nor is there any sense in subjecting the fatty and the volatile oils to the same reactions, just because they both bear the same designation "oils".

The application of Hübl's iodine addition method to volatile oils has been recommended by Barenthin,¹⁾ Kremel,²⁾ Williams,³⁾ Davies⁴⁾ and Snow.⁵⁾ By a direct comparison of the results of these separate observers it could not have been difficult for Cripps⁶⁾ to show the utter uselessness of this method. This result is not altered by the fact that individual analysts again and again recommend this method.⁷⁾

The use of bromine in place of iodine was first suggested by Levallois⁸⁾ and later by Klinont.⁹⁾ More recently it has again been recommended by Vaubel¹⁰⁾ and Mosler.¹¹⁾ In as much, however, as the variety in the composition of volatile oils renders it impossible to pass judgement as to which of the constituents

¹⁾ Arch. der Pharm. 221 (1886), 848.

²⁾ Pharm. Post 21 (1888), 789, 821.

³⁾ Chem. News 60 (1889), 175.

⁴⁾ Pharmaceutical Journ. III. 10 (1889), 821.

⁵⁾ Pharmaceutical Journ. III. 20 (1889), 4.

⁶⁾ Chem. News 60 (1889), 236.

⁷⁾ Sanglé-Ferrière and Cuniasse, Journ. de Pharm. et Chim. II. 17 (1903), 169; Report of Schimmel & Co. April 1903, 82; F. Hudson-Cox and W. H. Simmons, Analyst 29 (1904), 175; Pharmaceutical Journ. 72 (1904), 861; Report of Schimmel & Co. October 1904, 80; Worstell, Journ. Soc. chem. Industry 23 (1904), 302; Report of Schimmel & Co. October 1904, 85; Harvey, Journ. Soc. chem. Industry 23 (1904), 413; Report of Schimmel & Co. October 1904, 86.

⁸⁾ Compt. rend. 99 (1884), 977.

⁹⁾ Chem. Ztg. 18 (1894), 641.

¹⁰⁾ Zeitschr. f. öfl. Chem. 11 (1905), 429; Chem. Zentralbl. 1906, I. 199; Report of Schimmel & Co. April 1906, 66.

¹¹⁾ Zeitschr. d. allg. österr. Apoth. Ver. 45 (1907), 223, 235, 251, 267, 283, 299; Report of Schimmel & Co. October 1907, 116.

it is with which the bromine combines, the value of the results obtained will remain problematical. The method will, therefore, find application in emergency cases only.

According to Maumené's test the fatty oil to be investigated is mixed in a certain proportion with concentrated sulphuric acid and the rise in temperature which takes place is observed. Its application to volatile oils was recommended by Williams¹⁾ as well as by Duyk²⁾ but it has found just as little favor in practice as the other methods named above.

With these methods are also to be classed the much recommended color reactions. They mostly consist in bringing together a volatile oil and e. g. sulphuric acid or nitric acid, whereby some coloration is produced, which only in rare cases can be ascribed to a definite chemical change. As the shades of color produced are difficult to describe, and often change from one to the other, these tests may therefore easily give rise to mistakes. Hence the color reactions in general are to be designated as useless. This does not exclude, however, the occasional use of a color reaction in the detection of adulterants. This is especially true if these color tests are used for the characterization of chemical individuals isolated from the volatile oils (e. g. cadinene, sylvestrene). It is, however, never to be considered as conclusive in itself.

Besides the methods of testing already enumerated, many others have been suggested in the course of time, which however have acquired as little practical importance as these. Only such methods are to be discussed here as have really proven satisfactory in the investigation of volatile oils.

SAPONIFICATION.

Through scientific investigation it has been established that many volatile oils contain ester-like compounds, the components of which, on the one hand are alcohols, usually of the composition $C_{10}H_{18}O$ or $C_{10}H_{20}O$ and acid radicals of the fatty series, on the other.

¹⁾ Chem. News 61 (1890), 64.

²⁾ Bull. de l'Académie roy. de médec. de Belgique. 1897.

The esters, which are nearly without exception of a pleasant odor, are often to be considered as the most important constituents of the oils. Thus, linalyl acetate is the carrier of the odor in bergamot oil; the same ester is found in lavender oil and also occurs along with other compounds in petitgrain oil.

The esters of borneol, found in the different pine-needle oils, play an important part in the formation of the pine aroma. Menthyl acetate is found in the peppermint oils and the geranyl ester of tiglic acid in the different geranium oils.

The quantitative estimation of the ester is always valuable for judging the oils, even when the esters are of little consequence to the odor. But it is much more important, and really the only rational test of quality in such cases where the esters are the carriers of the characteristic odor, as with bergamot oil and with lavender oil. The determination is made according to the method of quantitative saponification, as it has long been used in the analysis of the fats. Its application to the volatile oils was first urged by A. Kremel.¹⁾ However, it did not acquire practical importance until the nature of the saponifiable compounds was ascertained through scientific investigation.

Kremel distinguishes acid value (acid v.), ester value (ester v.), and saponification value (sap. v.). The acid value expresses how many mg. of KOH are necessary to neutralize the amount of free acid contained in 1 g. of oil. The ester value gives the amount of potassa in milligrams used in the saponification of the ester contained in 1 g. of oil. The saponification value is the sum of acid value and ester value. As the volatile oils with exception of e. g. geranium oil and vetiver oil usually contain only a small amount of free acid, this may in general be neglected. Only old, partly spoiled oils, tend to show somewhat higher acid values. It is urged that in all cases the acid and ester values be determined separately, for the reason that acids are occasionally added to increase the apparent ester content.

It should be mentioned that in all oils which contain aldehydes, the ester determination by saponification cannot be made, as a consumption of alkali takes place due to the decomposition of the aldehyde which increases with the length of the reaction,

¹⁾ Pharm. Post 21 (1888), 789, 821.

but which gives no information as to the amount of aldehyde decomposed.

Errors in the determination likewise result from the presence of phenols. Hence these should first be removed with the aid of a dilute (3 to 5 percent) aqueous alkali, unless the ester determination is abandoned in such cases.



Fig. 73

The saponification is conducted in a wide necked flask of potash glass of 100 cc. capacity (fig. 73). A glass tube about 1 m. in length and passing through a stopper serves as a reflux condenser. Into such a flask about 1.5 to 2 g. of oil are weighed accurately to 1 cg. and about twice its volume of acid-free alcohol is added. After the addition of a few drops of alcoholic phenol-phthalein solution, half-normal potassa is carefully added. The reaction is completed when the red color produced no longer disappears upon shaking. A later decoloration is due to the saponification of the ester by the alkali. After the neutralization of the free acid, which usually

requires but 2 to 3 drops of halfnormal alkali, 10 cc. or more¹⁾ of the solution are added, and the mixture is heated on a water bath for an hour²⁾ after the usual precaution to prevent bumping

¹⁾ In most cases 10 cc. suffice. Only in the case of oils with high ester content (Roman chamomile oil, wintergreen oil) 20 to 30 cc. should be taken. Care should always be taken to have a sufficient excess of alkali. For the same reason 20 cc. of alkali should be taken when oils of unknown ester content are to be saponified. If esters as such are to be saponified even larger amounts should be used depending upon the size of the molecule and the number of carboxyl groups present. Thus, e.g. the saponification of 2 g. of methyl formate requires 67 cc. of halfnormal potassium hydroxide solution.

²⁾ The saponification of most esters can be accomplished in a much shorter time, that of the ester of bergamot oil being accomplished in 10 minutes. However, in order to be certain of the results and to work under the same conditions, the time of heating is extended whereby no harm is done. Comp. Report of Schimmel & Co. October 1883, 25. The method of Helbing (Helbing's Pharmacological Record No. 30, p. 4), according to which the saponification of bergamot oil is conducted in a closed vessel, hence under pressure, yields, as the investigations of Schimmel & Co. revealed, results that are 1 to 2 percent

has been taken and the reflux condenser has been adjusted. After cooling, the contents of the flask are diluted with 50 cc. of water and the excess of alkali is titrated with half-normal sulphuric acid.

The computation is carried out with the aid of the following formula:

$$\left. \begin{array}{l} \text{Acid. V. (Acid value)} \\ \text{Ester. V. (Ester value)} \\ \text{Sap. V. (Saponification value)} \end{array} \right\} \begin{array}{l} 28 \cdot a \\ s \end{array}$$

in which a stands for the number of cc. of half-normal alcoholic potassa solution and s for the number of grams of oil of uscd.

If for 1.5 g. of bergamot oil employed 0.1 cc. of half-normal potassa has been used to neutralize the free acid, 6.0 cc. for saponification, then

$$\begin{aligned} \text{the acid value (acid v.)} &= \frac{28 \cdot 0.1}{1.5} = 1.87; \\ \text{the ester value (ester v.)} &= \frac{28 \cdot 6.0}{1.5} = 112.0; \text{ and} \\ \text{the saponification value (sap. v.)} &= \frac{28 \cdot (0.1 + 6.0)}{1.5} = 113.87 = 1.87 + 112.0. \end{aligned}$$

From the ester value the percentage of ester or of alcohol respectively can be computed with the aid of the following formulas:

$$\text{" " ester} = \frac{\text{Ester V.} \cdot m}{560 \cdot b}; \quad \text{" " alcohol} = \frac{\text{Ester V.} \cdot m_1}{560},$$

in which m stands for the molecular weight of the respective ester, m_1 for that of the corresponding alcohol, and b for the basicity of the corresponding acid.

higher than those conducted in an open flask. The explanation lies in the fact that the linalool itself is affected by the caustic potash when heated with it under pressure whereas it suffers no change in the open flask. Later Helbing and Passmore [Chemist and Druggist 42 (1895), 585], substantiated the conclusion that the saponification in an open flask is to be preferred to that in an autoclave. Neither does the process of cold saponification appear to be applicable, which has the additional disadvantage of loss of time. According to Henriques (Zeitschr. f. angew. Chem. 1897, 399), linalool reveals a saponification value of 4.2, geraniol one of 2.8 when acted upon by alkali for 12 hours. In isolated cases only boiling for one hour does not suffice for the quantitative saponification of esters, thus e. g. with terpinyl acetate, bornyl and menthyl isovalerate, which must be boiled for from 2 to 3 hours with a sufficient excess of alkali.

For the more common alcohols found in volatile oils, *viz.*, $C_{10}H_{18}O$ (geraniol, linalool, borneol, *isopulegol*), $C_{10}H_{20}O$ (menthol, citronellol), $C_{15}H_{21}O$ (santalol), $C_{15}H_{25}O$ (cedrol), and their esters the formulas read as follows:

| | | | |
|-------------------------------------|---------------------|-----------|---------------------|
| 1. $C_{10}H_{18}O$: % acetic ester | Ester V. 196 560 | % alcohol | Ester V. 154 560 |
| 2. $C_{10}H_{20}O$: % acetic ester | Ester V. 198 560 | % alcohol | Ester V. 156 560 |
| 3. $C_{15}H_{21}O$: % acetic ester | Ester V. 262 560 | % alcohol | Ester V. 220 560 |
| 4. $C_{15}H_{25}O$: % acetic ester | Ester V. 264 560 | % alcohol | Ester V. 222 560 |

In the above formulas the factor *b* drops out since acetic acid is monobasic.

For the bergamot oil illustration given on the previous page, the ester of which is linalyl acetate ($CH_3COOC_{10}H_{17}$) and the alcohol of which is linalool ($C_{10}H_{18}O$), the following values result:

$$\begin{aligned} \% \text{ linalyl acetate} &= \frac{112.0 \cdot 196}{560} = 39.20, \\ \% \text{ linalool} &= \frac{112.0 \cdot 154}{560} = 30.80. \end{aligned}$$

Avoiding the ester value, the percentage of ester and of alcohol can be computed directly with the aid of the following formulas:

$$\% \text{ ester} = \frac{a \cdot m}{20 \cdot s \cdot b}; \quad \% \text{ alcohol} = \frac{a \cdot m_1}{20 \cdot s}.$$

In these formulas the symbols have the same significance as in the previous formulas.

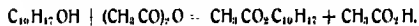
For the alcohols mentioned above, *viz.*, $C_{10}H_{18}O$, $C_{10}H_{20}O$, $C_{15}H_{21}O$ and $C_{15}H_{25}O$, tables will be found at the end of this chapter (table I, p. 618), in which the percentage of acetic ester and of alcohol can be found for each ester value.¹⁾ The use of the table is quite apparent without further explanation. If in a given case 112 has been found as the ester value for bergamot oil, all that is necessary is to trace the corresponding figure in the column headed $C_{10}H_{18}O$ and in the one headed "acetate", *viz.*, 39.20. This figure reveals the percentage of linalyl acetate in bergamot oil, whereas the corresponding number 30.80 in the column headed "alcohol" reveals the percentage of linalool.

¹⁾ For geraniol the percentage of tiglate is also given. Table I, p. 618.

In order to save time in the computation of these alcohols, a second table (table II, p. 632) has been added in which the ester value (acid value, saponification value) as well as the corresponding percentage content of acetate or alcohol can be traced from the number of cc of half-normal potassium hydroxide solution used, provided exactly 1.50 g. of oil have been employed.

ACETYLATION.

Many volatile oils contain as important constituents alcohols varying in composition, for instance, borneol, geraniol, terpineol, linalool, thujylalcohol, menthol, citronellol and santalol. For the quantitative estimation, their behavior toward acetic acid anhydride, with which they form acetic esters when heated, may be used. Taking geranyl acetate as an illustration, their formation takes place according to the equation:



For the quantitative acetylation¹⁾ 10 cc. of the oil, mixed with an equal volume of acetic acid anhydride and about 2 g. of dry sodium acetate, are boiled uniformly for 1 hour in a small flask provided with a condensing tube which is ground into the neck of the flask and some small fragments of tiling to prevent bumping (fig. 74). After cooling, some water is added to the contents of the flask and then heated for $\frac{1}{4}$ hour on a water bath, to decompose the excess of the acetic acid anhydride. The oil is then separated in a separating funnel, and washed with water, or better still with sodium chloride solution, until the reaction is neutral.²⁾

The acetylated oil, dried with anhydrous sodium sulphate, 1.5 to 2.0 g. are saponified with 20 cc. of half-normal potassium



Fig. 74

¹⁾ Report of Schimmel & Co. October 1894, 62.

²⁾ One can also proceed to neutralize the free acid with sodium carbonate solution and then to wash with water until the reaction is neutral. In this case, however, one occasionally encounters the difficulty of removing the soda solution from the oil, a difficulty that is obviated when proceeding as indicated above.

hydroxide solution according to the method described on p. 572, any free acid present having previously been carefully neutralized. The percentage of alcohol corresponding to the ester value found, and referring to the original non acetylated oil, can be looked up in the table appended to this chapter, viz., table I'), p. 618. These values are derived with the aid of the following formula:

$$\% \text{ alcohol in the original oil} = \frac{a \cdot m}{20 \cdot (s - a \cdot 0,021)} \text{ in which}$$

m the molecular weight of the respective alcohol,

a the number of cc. of half-normal potassium hydroxide solution

s the number of grams of acetylated oil used. [used,

Attention should, however, be directed to the circumstance that this formula does not take into consideration that a part of the alcohol may be contained as ester in the original oil. A small percentage of ester in the original oil may be disregarded since the error caused thereby is small. If, however, the ester content is large, or if more accurate results are desired, this error should be eliminated. For this purpose the amount of free alcohol is computed from the difference between the ester number of the original oil and the ester number of the acetylated oil (table I, p. 618, alcohol in original oil). To this is added the amount of esterified alcohol computed from the ester number. The sum is that of the percentage of total alcohol.

By way of illustration. A peppermint oil has yielded 26,43 as ester value before and 173,57 as ester value after acetylation. In order to ascertain the amount of total menthol present one proceeds as follows:

$$173,57 - 26,43 = 147,14 = 46,07 \text{ p. c. of free menthol;}$$

$$26,43 \quad 7,36 \text{ p. c. of ester menthol;}$$

$$\text{hence total menthol} = 46,07 + 7,36 = 53,43 \text{ p. c.}$$

Without this recalculation the amount of total menthol, as computed from the ester value after acetylation, would be 55,59 p. c.

¹⁾ When 1,50 g. of acetylated oil are used the alcohol content can be ascertained directly with the aid of table II on p. 632 from the number of cc. of half-normal potassium hydroxide solution employed.

The values obtainable from the ester content can also be expressed by means of the following formulas:

$$\begin{aligned} \% \text{ of free alcohol in the orig. oil} &= \frac{m \cdot (a_2 - a_1)}{20 \cdot [s - (a_2 - a_1) \cdot 0.021]} \\ \% \text{ of total alcohol in the orig. oil} &= \frac{m \cdot [a_2 \cdot s - (a_2 - a_1) \cdot a_1 \cdot 0.021]}{20 \cdot s \cdot [s - (a_2 - a_1) \cdot 0.021]} \end{aligned}$$

In the above formulas

m stands for the molecular weight of the respective alcohol,
 a_1 for the number of cc. of half-normal potassium hydroxide solution consumed by s grams of the original oil,

a_2 for the number of cc. of half-normal potassium hydroxide solution consumed by s grams of acetylated oil.

Hence in both instances the amounts of potassium hydroxide solution pertain to equal amounts of oil.

For purely practical reasons the statements found in the second volume as to the total alcohol are made throughout without reference to the ester content of the original oils. In other words, they are the values derived directly from the ester values of the acetylated oil. For practical purposes this will suffice in general, as the differences are not appreciable. In the case of geranium oil, however, appreciable differences occur. This is due not only to the presence of a higher ester content, but also to the fact that the esterified alcohol of the original oil is combined with tiglic acid, whereas the formula considers only acetic acid. In this instance, therefore, the amount of originally esterified alcohol and the amount of free alcohol receive separate consideration; also the total amount of alcohol derived from the two is recorded. But here also the apparent alcohol content derived from the acetylation value (ester value after acetylation) is also recorded.

The reaction between alcohol and acetic acid anhydride is quantitative in the case of borneol, isoborneol, geraniol,¹⁾ menthol²⁾ and santalol, hence enables an accurate determination of these substances. Less fortunate are the conditions with the tertiary alcohols linalool and terpineol, as these, on boiling with acetic acid anhydride, are partly decomposed by splitting off water

¹⁾ Bertram and Gildemeister, Journ. f. prakt. Chem. II. 49 (1894), 189.

²⁾ Power and Kieber, Pharm. Rundsch. (New York) 12 (1894), 162; Arch. der Pharm. 232 (1894), 653.

with the formation of terpenes. Comparative figures, however, can also be obtained with these alcohols if the same amount of acetic acid anhydride is always used and the boiling continued for the same length of time. With linalool there was found as a favorable result after 2 hours of boiling, a deficiency of 15 percent of alcohol.¹⁾ Terpineol behaves toward acetic acid anhydride as follows:

| Time of boiling: | Terpinyl acetate formed: |
|------------------|--------------------------|
| 10 minutes | 51,2 percent |
| 30 " | 75,5 " |
| 45 " | 84,4 " |
| 2 hours | 77,9 " |

With terpineol, therefore, heating longer than 45 minutes has a detrimental effect.

Better results are obtained if the suggestion of Boulez²⁾ is followed and a diluent in the ratio of 1:5 is employed. For this purpose either turpentine oil or xylene may be used. Turpentine oil, however, yields a small acetylation number for which a correction should be made, whereas xylene remains totally unchanged. At the same time the period of acetylation must be prolonged. Schimmel & Co.³⁾ report that the maximum of ester determination is reached after boiling 5 to 7 hours. Longer boiling again reduces the amount of ester formed as shown by the following table.

Even with this modification, satisfactory results are obtained only with terpineol, whereas the accuracy of the results obtained with linalool leaves much to be desired. The quantitative acetylation reported to have been observed by Boulez depended on wrong computation as pointed out by Schimmel & Co.³⁾

I. 20 parts linalool - 80 parts xylene.

| Duration of acetylation | 3 hrs. | 5 hrs. | 7 hrs. | 12 hrs. | 20 hrs. |
|---|--------|--------|--------|---------|---------|
| Ester v. | 53,3 | 60,4 | 63,0 | 63,3 | 51,6 |
| % $C_{10}H_{18}O$ | 15,3 | 17,4 | 18,2 | 18,3 | 14,8 |
| Found with reference to 100 parts of the alcohol | 76,5 | 87,0 | 91,0 | 91,5 | 73,8 |

¹⁾ Report of Schimmel & Co. April 1893, 45.

²⁾ Corps gras industriels 33 (1907), 178; Bull. Soc. chim. IV. 1 (1907), 117.

³⁾ Report of Schimmel & Co. April 1907, 121.

The values obtainable from the ester content can also be expressed by means of the following formulas:

$$\begin{aligned} \text{“% of free alcohol in the orig. oil} &= \frac{m \cdot (a_2 - a_1)}{20 \cdot [s - (a_2 - a_1) \cdot 0.021]} \\ \text{“% of total alcohol in the orig. oil} &= \frac{m \cdot [a_2 \cdot s - (a_2 - a_1) \cdot a_1 \cdot 0.021]}{20 \cdot s \cdot [s - (a_2 - a_1) \cdot 0.021]} \end{aligned}$$

In the above formulas

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 a_1 for the number of cc. of half-normal potassium hydroxide solution consumed by s grams of the original oil,

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¹⁾ Bertram and Gildemeister, Journ. f. prakt. Chem. II. 49 (1894), 189.

²⁾ Power and Kieber, Pharm. Rundsch. (New York) 12 (1894), 162; Arch. der Pharm. 232 (1894), 653.

Verley and Bölsing¹⁾ have tried to simplify the acetylation process. They esterify the oil with a definite amount of acetic acid anhydride in the presence of pyridine, titrate the acetic acid not combined with the alcohol, and compute the alcohol content. The method has not proven satisfactory with the terpene alcohols, but yields better results with the phenols. Hence it is applied, if at all, in connection with the latter (comp. p. 593).

In like manner, the attempts to apply Schryver's method for the determination of phenols (p. 592) to alcohols has proven a failure.²⁾

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As has already been pointed out under citronellol (p. 365), this alcohol is converted into the formate when boiled with formic acid, whereas other terpene alcohols, such as geraniol and linalool, are either dehydrated to terpenes or are completely decomposed: The course of the reaction is so quantitative that it can be utilized for the assay of citronellol-containing oils.³⁾ In the presence of larger amounts of other alcohols the results are apt to be too high, due to the disturbance in the ratio of constituents produced by the formation of water. For practical purposes, however, the results may suffice.

The formylation is effected by heating for an hour 10 cc. of oil with twice its volume of strong formic acid ($d_{15} 1,226$) in an acetylation flask either on a water bath or better still on a sand bath so as to maintain gentle boiling. If a water bath is used the mixture should be shaken repeatedly. When cooled the contents of the flask are diluted with water and washed until neutral. The remaining part of the process is conducted as described under acetylation.

The citronellol content can be computed with the aid of the following formula:

$$^{100} C_{10}H_{20}O = \frac{a \cdot 7,8}{s - a \cdot 0,014}$$

in which a represents the number of cc. of half-normal alcoholic

¹⁾ Berl. Berichte 34 (1901), 3354.

²⁾ Report of Schimmel & Co. October 1904, 129.

³⁾ Report of Schimmel & Co. April 1901, 47.

The values obtainable from the ester content can also be expressed by means of the following formulas:

$$\begin{aligned} \text{“% of free alcohol in the orig. oil} &= \frac{m \cdot (a_2 - a_1)}{20 \cdot [s - (a_2 - a_1) \cdot 0.021]} \\ \text{“% of total alcohol in the orig. oil} &= \frac{m \cdot [a_2 \cdot s - (a_2 - a_1) \cdot a_1 \cdot 0.021]}{20 \cdot s \cdot [s - (a_2 - a_1) \cdot 0.021]} \end{aligned}$$

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²⁾ Power and Kieber, Pharm. Rundsch. (New York) 12 (1894), 162; Arch. der Pharm. 232 (1894), 653.

hydrazine, after some time the hydrazone which has formed is separated by filtration, and the unchanged phenyl hydrazine in the filtrate oxidized with boiling Fehling's solution. By this treatment all the nitrogen of the phenyl hydrazine which has not taken part in the reaction is liberated as gas. From the volume of the collected nitrogen the amount of the unused phenyl hydrazine can be calculated. From this the amount which has gone into combination is known and consequently the amount of the ketone or aldehyde present. The amount of carbonyl oxygen, expressed in $\frac{1}{10}$ percents is designated as carbonyl number.

With bitter almond oil (benzaldehyde), cumin oil (cuminic aldehyde), and rue oil (methyl nonyl ketone) this method yields fairly good results. With cassia oil, caraway oil, fennel oil and lemon oil, however, the determinations fall far too low,¹⁾ possibly because the time allowed does not suffice for the quantitative completion of the reaction.

The modification of the above method proposed by Rother²⁾ has met with a similar fate. It likewise yields satisfactory results in a few instances only. The aldehydes and ketones are converted into phenylhydrazones by means of a definite amount of phenylhydrazine. It differs, however, from the original method in this that the excess of phenylhydrazine is allowed to react with iodine and the excess of iodine is titrated with thiosulphate solution.

For the assay of aldehydes and ketones we are, therefore, dependant on several methods, of which the most important in actual practice are here described. The determination is mostly volumetric or titrimetric, seldom gravimetric. The best known and most commonly used method is the

Bisulphite method. It was first introduced in 1890³⁾ by Schimmel & Co. for the cinnamic aldehyde assay of cassia oil. At present it plays an important role in the assay of oils containing cinnamic aldehyde or citral. The method depends on the property of both cinnamic aldehyde and citral to dissolve in hot concentrated sodium bisulphite solution with the formation of sulphonates, hence can be abstracted quantitatively from the oils, whereas the

¹⁾ Report of Schimmel & Co. October 1903, 52.

²⁾ *Die Bestimmung der Aldehyde und Ketone zur Beurteilung ätherischer Öle.* Inaug. Dissert. Dresden 1907.

³⁾ Report of Schimmel & Co. October 1890, 15.

non-aldehyde constituents remain undissolved. The amount of dissolved oil reveals its aldehyde content.

For this determination a special glass flask (cassia flask, aldehyde flask, fig. 75) is used. It has a capacity of about 100 cc., is provided with a neck 13 cc. long, the inner diameter of which is 8 mm., and which is calibrated into $\frac{1}{10}$ cc. The entire neck of the flask has a capacity of about 6 cc. The zero point of the scale is placed slightly above the transition point of the flask into the neck.

By means of a pipette, 10 cc.¹⁾ of oil are transferred to the flask and an equal volume of 30 p. c. sodium acid sulphite²⁾ solution is added. The mixture is shaken and the flask placed in a boiling water bath. After the solid mass has become liquid more acid sulphite solution is added until the flask is at least three-quarters full, the mixture being constantly heated and occasionally shaken. The solution is heated until no more solid particles are visible and the odor of aldehyde has disappeared. When the clear oil floats upon the salt solution, flask and contents are allowed to cool and sufficient acid sulphite solution is added until the oily layer is well within the neck of the flask. Should drops of oil adhere to the flask these are induced to rise into the neck by gentle tapping and rotation of the flask. The number of cc. of oil is read off, and by deducting this number from ten, the aldehyde content in percentage by volume is ascertained by multiplying the resultant with ten. In order to obtain the percentage by weight the number obtained is multiplied with the specific gravity of the aldehyde in question and the product divided by the specific gravity of the oil.



Fig. 75.

¹⁾ In the case of oils that contain less than 40 p. c. of aldehyde only 5 cc. are taken or a flask is used the neck of which has a capacity of 10 cc. and is calibrated from 1 to 10.

²⁾ Care should be taken that the solution does not contain too much free sulphurous acid since this retards the reaction. If necessary, the solution should be neutralized somewhat by the addition of sodium carbonate.

As already pointed out, this method is used for the quantitative determination of cinnamic aldehyde and citral, which go into solution as sulphonates. It can, however, be used also in connection with those aldehydes the bisulphite addition products of which are soluble in water as such, e. g. benzaldehyde, anisic aldehyde, phenyl acetaldehyde. 10 cc. of the aldehyde in question are shaken with 40 to 50 cc. of a 30 p. c. sodiumbisulphite solution in an aldehyde flask, and the reaction product dissolved, with the aid of gentle heat, in additional water (not sodium bisulphite solution). The oil that has not taken part in the reaction is driven into the calibrated neck by adding more water. Its volume is read off as soon as the contents of the flask have assumed room temperature. Prolonged standing frequently causes the bisulphite compound to crystallize out again.

Closely related to the bisulphite method is the

Sulphite method, which is based on the observation that certain aldehydes and ketones react with neutral sodium sulphite to form water soluble compounds with the simultaneous formation of sodium hydroxide. In as much as the latter tends to reverse the reaction, it should be neutralized with dilute acid from time to time as it is formed. It was Tiemann¹⁾ who, in connection with his studies on citral, first pointed to the application of this reaction for quantitative determinations. Somewhat later Sadtler²⁾ claimed that the method was generally applicable for the quantitative determination of saturated and unsaturated aldehydes both of the aliphatic and aromatic series, and was also applicable in the case of several ketones. According to his method the free alkali is titrated with half-normal hydrochloric acid. It suffers from the disadvantage that the sodium sulphite solution cannot be titrated sharply, hence the end of the reaction can be determined only approximately. Accurate results are, therefore, not obtainable.

Practical significance the sulphite method has acquired only through the modification suggested by Burgess.³⁾ The process is as follows:

¹⁾ Berl. Berichte 31 (1898), 3317.

²⁾ Americ. Journ. Pharm. 76 (1904), 84; Journ. Soc. chem. Industry 23 (1904), 303; Journ. Americ. chem. Soc. 27 (1905), 1321.

³⁾ Analyst 29 (1904), 78.

To 5 cc. of the oil to be examined and contained in a cassia flask¹⁾ a freshly prepared saturated (40 p. c.) solution of neutral, crystalline sodium sulphite and a few drops of phenolphthalein are added. The mixture is heated in a water bath while frequently shaken. The sodium hydroxide set free is almost neutralized from time to time with dilute acetic acid (1:5) until even the addition of more sodium sulphite solution causes no further reddening while the mixture is being heated. Water is then added to drive the non-dissolved oil into the neck of the flask where, upon cooling, its volume is read off on the scale. Multiplication of the number of cc. of oil with 20 yields the volume percentage of aldehyde or ketone in the oil.

Although this method is by no means as applicable²⁾ as claimed by Sadtler and Burgess, it is applicable in several cases where the bisulphite method fails. Its principal value lies in the possibility to assay carvone and pulegone, of which the former reacts smoothly and rapidly with neutral sodium sulphite. In the case of pulegone the reaction is much slower, several hours being required at times to bring the process to completion.

Satisfactory results are also obtained with citral and cinnamic aldehyde. It should be remembered, however, that the results may deviate somewhat from those obtained with the bisulphite method in the case other aldehydes are present. This is true *e. g.* in the case of lemongrass oil which gives higher results with the bisulphite method than with the sulphite method. This is due to the fact that neutral sodium sulphite reacts with citral only whereas the other aldehydes present in lemongrass oil, likewise a part of the methylheptenone react with the bisulphite. It is urged, therefore, that in connection with statements as to the aldehyde content of oils, the method be mentioned according to which the aldehyde assay was made.

Which of the two methods is to be preferred in individual cases depends altogether on the nature of the oil in question.

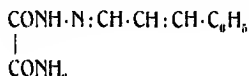
¹⁾ Burgess makes use of a flask of 200 cc. capacity which differs from the ordinary cassia flask in being furnished with a tube, attached to the side of the neck, that leads to the bottom of the flask and serves for the addition of the liquids. The common cassia flasks, however, are much more convenient and serviceable, but it is best to use one with 200 cc. capacity and to take 10 cc. of oil for the sake of greater accuracy.

²⁾ Report of Schimmel & Co. April 1905, 103.

According to Burgess, one of the advantages of the sulphite method consists in the absence of crystalline deposits which are occasionally formed at the zone of contact between oil and water in the case of the bisulphite method and which disturbing factor at times prevents an accurate reading of the volume of the oily layer. Schimmel & Co., however, observed that such depositions are also produced in the case of the sulphite method.

For the assay of cinnamic aldehyde the gravimetric method of Hanuš¹⁾ can be utilized. It yields very accurate results and is especially applicable when only small amounts of oil are available. In the case of the Ceylon cinnamon oil, the results deviate from those obtained with the bisulphite method by as much as 4 to 5 p. c., even if the latter are computed in percentage by weight. Presumably this difference is due to the presence of other aldehydes which are determined with the cinnamic aldehyde by the bisulphite method.²⁾

Hanuš separates the cinnamic aldehyde as semioxamazone



and proceeds according to the following method:

To 0.15 to 0.2 g. of oil, contained in a 250 cc. Erlenmeyer flask, 85 cc. of water are added and the oil finely divided by shaking. In order to make possible a fine division of the oil and thus to prevent a part of the aldehyde to be coated by semioxamazone thereby preventing it from taking part in the reaction, it is expedient to dissolve the oil in 10 cc. of alcohol (95 to 96 per cent by volume) before adding the water. One and one-half times the amount of semioxamazide,³⁾ dissolved in 15 cc. of hot water, are then added and the mixture shaken thoroughly for 5 minutes. It is then set aside for 24 hours with occasional shaking. Care should be taken to shake the mixture repeatedly during the first three hours. The flocculent precipitate of semi-

¹⁾ Zeitschr. Untersuch. der Nahrungs- u. Genussmittel 6 (1903), 817. Comp. also Report of Schimmel & Co. April 1904, 19.

²⁾ Report of Schimmel & Co. April 1904, 21.

³⁾ As to the method of preparation comp. Kerp and Unger, Berl. Berichte 30 (1897), 585; also Weddige, Journ. f. prakt. Chem., 10 (1874), 196.

oxamazone is filtered by means of a Gooch crucible (prepared with asbestos, dried and weighed), washed with cold water and dried at 105° until of constant weight. If a is the amount of cinnamic aldehyde semioxamazone, s the amount of oil used, the percentage of cinnamic aldehyde can be computed with the aid of the formula

$$\frac{a \cdot 60,83}{s}$$

This method can also be used for determining the amount of cinnamic aldehyde in cinnamon bark. For this purpose Hanuš gives special directions.

For the determination of small amounts of aldehyde neither the bisulphite nor the sulphite method is adapted since both yield results that may vary from 1 to 2 p. c. Hence the error is too great for small amounts of aldehyde. For cinnamic aldehyde the method of Hanuš affords a reliable assay in such cases.

Small amounts of benzaldehyde can be determined, according to Hérissay,¹⁾ as phenylhydrazone according to the following method:

50 cc. of the solution to be examined, which should contain only so much aldehyde as to yield 0,1 to 0,25 g. of phenylhydrazone, are mixed with a solution of 0,5 cc. freshly distilled phenylhydrazine and 0,25 cc. glacial acetic acid in 50 cc. of water and the mixture heated for 20 to 30 minutes on a water bath. After 12 hours the phenylhydrazone formed is filtered through a weighed Gooch crucible, washed with 20 cc. water and dried in a vacuum desiccator.

Very similar is the method of Denis and Dunbar.²⁾ Woodman and Lyford³⁾ have suggested a colorimetric method for this purpose which need not be considered here.

The problem of the citral assay of lemon oil, which contains about 4 to 7 p. c. of this aldehyde, has received much attention from chemists, particularly in recent years. Of the many methods proposed not one has thus far been found practi-

¹⁾ Journ. de Pharm. et Chim. VI. 23 (1906), 60.

²⁾ Journ. Ind. and Eng. Chem. 1909, 256. According to Chem. Ztg. Repert. 33 (1909), 281.

³⁾ Journ. Americ. chem. Soc. 30 (1908), 1607.

cable since all fall short in the desired degree of accuracy. (For details see under oil of lemon.) If approximate results are sufficient the method proposed by Walther¹⁾ and as improved by A. H. Bennet²⁾ can be recommended: To a mixture of 20 cc. lemon oil with 20 cc. alcoholic (80 p. c. alcohol) half-normal hydroxylamine hydrochloride solution, 8 cc. of alcoholic normal potassium hydroxide solution and 20 cc. of strong, aldehyde-free alcohol are added and the whole boiled for 1/2 hour, the flask being connected with a reflux condenser. After cooling the contents are diluted with 250 cc. of water, part of which is used to rinse the condenser. The hydrochloric acid still combined with hydroxylamine is then neutralized, phenolphthalein being used as indicator. The hydroxylamine not combined with citral can now be titrated with half-normal sulphuric acid, the end of the reaction being ascertained by testing a drop at a time with dilute methylorange solution. A blank test is made in like manner without lemon oil for the purpose of determining the hydroxylamine factor. The difference between the number of cc. of half-normal sulphuric acid used in both tests reveals the amount of hydroxylamine that has entered into reaction. By multiplying this with 0.076 the amount of citral can be computed.

As has been ascertained by Schimmel & Co.³⁾ the results obtained by this method average about 10 p. c. too low as compared with the amount of citral present. For lemon oils, with their low citral content, the error may not be too great, but for oils, such as lemongrass, with a high percentage of aldehyde the method cannot be used.

Vanillin. For the assay of vanillin, its compounds with *β*-naphthylhydrazine and *p*-bromophenylhydrazine may, according to Hanuš,⁴⁾ be utilized. For every part of vanillin 2 to 3 parts of hydrazine are taken. After 5 hours the reaction products are collected in a Gooch crucible, washed, and dried at 90 to 100° until of constant weight.

¹⁾ Pharm. Zentralh. 40 (1899), 621; 41 (1900), 614.

²⁾ Analyst 34 (1909), 14. According to Zentralbl. 1909, I, 593.

³⁾ Report of Schimmel & Co. October 1909, 153.

⁴⁾ Zeitschr. Untersuch. der Nahrungs- u. Genussmittel 3 (1900), 531. According to Chem. Zentralbl. 1900, II, 693.

oxamazone is filtered by means of a Gooch crucible (prepared with asbestos, dried and weighed), washed with cold water and dried at 105° until of constant weight. If a is the amount of cinnamic aldehyde semioxamazone, s the amount of oil used, the percentage of cinnamic aldehyde can be computed with the aid of the formula

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²⁾ Journ. Ind. and Eng. Chem. 1909, 256. According to Chem. Ztg. Repert. 33 (1909), 281.

³⁾ Journ. Americ. chem. Soc. 30 (1908), 1607.

Menthone. Thus far the direct assay of menthone has not been a success. Hence one is still dependent on the indirect method first proposed by Power and Kleber,¹⁾ whereby the ketone is reduced to menthol by means of sodium and alcohol, and the menthol determined quantitatively. As has been shown in connection with mixtures of known menthone content, approximate results only are obtained. For practical purposes they may, however, suffice in most instances. The assay is carried out as follows: 15 cc. of oil, contained in a round bottomed flask, are diluted with about four times their volume of absolute alcohol,²⁾ the flask connected with a reflux condenser and the solution heated to boiling. To the boiling solution 5 to 6 g. metallic sodium are added very gradually. After all of the sodium has been consumed, the mixture is allowed to cool, diluted with water and acidulated with acetic acid. By means of a separating funnel the oil is separated from the aqueous liquid, washed repeatedly with sodium chloride solution for the purpose of removing completely the ethyl alcohol, and dried with anhydrous sodium sulphate. By means of acetylation the menthol content of the original as well as that of the reduced oil is ascertained, thus revealing the amount of menthol produced by the reduction. From this the amount of menthone contained in the original oil can be computed. If the original oil contained m_1 % total menthol, and the reduced oil m_2 %, the percentage of menthone of the original oil follows from the formula

$$\frac{(m_2 - m_1) \cdot 154}{156}$$

Ionone. For the quantitative determination of ionone see p. 468.

PHENOL DETERMINATION.

For the determination of phenols the method of shaking out with dilute sodium hydroxide solution has proven satisfactory.

¹⁾ Pharm. Rundsch. (New York) 12 (1894), 162; Arch. der Pharm. 282 (1894), 655.

²⁾ Absolute alcohol is preferable to such containing water, since the reduction is more complete and the sodium alcoholate formed is kept better in solution. Beckmann, Journ. f. prakt. Chem. II. 55 (1897), 18.

It was first applied by Gildemeister¹⁾ to oil of thyme, is readily carried out and for practical purposes is sufficiently accurate. In as much as all phenols yield water-soluble compounds with the alkalis, the method is quite generally applicable for volatile oils. However, as has been pointed out by Schimmel & Co.,²⁾ the concentration of the alkali³⁾ has to be chosen with reference to the phenol to be determined. For thymol or carvaerol-containing oils (oils of ajowan, thyme, Cretian origanum oil) a five percent solution is employed as originally suggested by Gildemeister (*loc. cit.*). Eugenol-containing oils (oils of clove, clove stems, pimenta, bay and cinnamon leaves), however, are to be shaken out with a three percent solution. If in the latter case a stronger solution is used, the results obtained are too high, for the excess of alkali together with the eugenol alkali exercise a solvent capacity on the nonphenol constituents, more particularly those containing oxygen. It may happen that oils with a high eugenol content are completely dissolved in the alkali. For this reason Umney's⁴⁾ proposition to use a 10 to 12 p. e. caustic potash solution is to be rejected, for the results obtained are always too high. The idea might readily suggest itself always to use a three percent solution. However, it has been shown that thymol and carvaerol are not quantitatively removed by such a solution.

The assay is conducted in the following manner: To 10 cc. of oil contained in a cassia flask that has a capacity of at least 100 cc. (fig. 75, p. 583) enough three or five percent caustic soda solution is added to fill the flask about four-fifths. The mixture is thoroughly and repeatedly shaken. That portion of the oil which has not entered into reaction is driven into the neck of the flask by the addition of more lye. Gentle tapping or rotation of the flask are resorted to, if necessary, to cause any oily drops that adhere to the glass walls to rise into the neck. After all of the nonphenols have risen into the neck, a process that usually

¹⁾ Hager, Fischer and Hartwich, *Kommentar zum Arzneibuch für das Deutsche Reich. 3. Ausgabe.* Berlin 1892. 1. Ed., Vol. II, p. 377.

²⁾ Report of Schimmel & Co. April 1907, 118.

³⁾ It should be specially mentioned that it makes no difference whether soda lye or potash lye be used. Because of the higher molecular weight of the latter, somewhat more solution, however, will have to be used.

⁴⁾ Pharmaceutical Journ. III. 25 (1895), 951.

requires several hours, their volume is read off by means of the calibration. Subtracting this number from 10 yields the amount of oil dissolved and multiplication of this number with 10 the phenol content of the oil expressed in volume percent.

In the case of oil of cloves, the mixture is heated in a water bath for 10 minutes. The object of this is to saponify the acetugenol, which is of equal value in the assay of the oil, and to determine it together with the free eugenol.

In place of the cassia flask a large burette can be used. In as much as these burettes, as a rule, have a capacity of but 60 cc., they should be used only where a five percent lye is applicable. Otherwise it might occur that the amount of alkali should prove insufficient for the complete solution of the phenol. In the case of oil of cloves a cassia flask will be used for the reason that the mixture is to be heated on a water bath.

If for the purpose of identification the phenol is to be isolated, the phenol-containing lye is separated from the oil, filtered through a moist, hardened filter, and the phenol regenerated by means of dilute sulphuric acid. The liberated phenol is shaken out with ether, the solution transferred to an evaporating dish, and the ether evaporated. The residual phenol can be identified by means of suitable derivatives. Thymol is identified readily since it solidifies upon cooling either by itself or when inoculated with a fragment of thymol.

Other methods for the quantitative determination of phenols have been worked out by Schryver, by Verley and Boelsing, and by Hesse. However, they are not used as commonly as the one described. Under special circumstances, however, the one or the other method may prove useful, more particularly if only little oil is available.

Schryver¹⁾ makes use of the property of sodium amide, NaNH_2 , to react with the phenols in such a way that the phenol hydrogen is replaced by the sodium and ammonia is set free. The latter is combined with acid and titrated.

The process is carried out in the following manner: About 1 g. of sodium amide is reduced to a fine powder, washed two or three times by decantation with benzene, and transferred to

¹⁾ Journ. Soc. chem. Industry 18 (1899) 553.

a 200 cc. flask with a wide neck, which is provided with a separating funnel and a condenser. 50 to 60 cc. of benzene free from thiophene are then transferred to the flask and boiled on a water bath. At the same time air free from carbon dioxide is drawn into the flask by means of a suction pump and through the separating funnel, the stem of which passes beneath the surface of the benzene. After boiling for ten minutes the last traces of ammonia adhering to the sodium amide have been drawn off. 20 cc. of normal sulphuric acid are then given into a receiver and this connected with the condenser. Now a solution of 1 to 2 g. of the phenol or of the volatile oil are allowed to flow slowly from the separating funnel into the boiling mixture of sodium amide and benzene. The separating funnel is washed with some benzene and air is sucked through the apparatus until all of the ammonia has been absorbed by the acid in the receiver. This usually requires one and a quarter hours. Finally, the excess of sulphuric acid in the receiver is titrated with sodium carbonate solution, methyl orange being used as indicator. The result is expressed as percent of phenol or, in the case of unknown phenols, as hydroxyl number. The "hydroxyl value" is defined by Schryver as the number of cc. of normal sulphuric acid necessary to neutralize the ammonia set free by 1 g. of substance if the conditions described above are followed.

This method, which determines only free phenols, is applicable only for such oils that are free from alcohols, aldehydes and ketones, to those oils that are mixtures of phenols and terpenes.¹⁾ On account of the great capacity of the amide to react with water, the oils must be, in addition, absolutely free from moisture.

The method of Verley and Baelsing²⁾ is based on the observation that the phenols react energetically in the cold with acetic acid anhydride provided pyridine be present. The acetic acid resulting combines directly with pyridine. In as much as pyridine is neutral towards phenolphthalein, the acetic acid not combined with phenol can be determined titrimetrically. For the assay about 3 g. of oil are heated for 15 minutes with 25 cc. of a mixture of 120 g. acetic acid anhydride and 880 g. pyridine

¹⁾ Report of Schimmel & Co. October 1904, 129.

²⁾ Berl. Berichte 34 (1901), 3354.

in a 200 cc. flask without condenser on a water bath. Upon cooling an equal volume of water is added to convert any unchanged acetic acid anhydride into acetic acid, *i. e.*, into pyridine acetate. The acetic acid not combined with phenol is then titrated back, using phenolphthalein as indicator. In like manner the acetic acid content of 25 cc. of the mixture is established. Subtraction reveals the amount of acetic acid combined with the phenol, whence the phenol content of the oil can be computed.

Phenol present as ester, *e. g.*, acetugenol in oil of cloves, is not determined by this method. However, it should be noted that the oils to be examined should contain no alcohols since these react like the phenols.

According to the method proposed by Hesse,¹⁾ phenols and more particularly phenol carboxylic esters, such as salicylic acid, can be determined. The oil to be examined is dissolved as such, or after previous dilution with an indifferent solvent (benzyl alcohol) in three parts of anhydrous ether. To the cooled solution half-normal alcoholic potassium hydroxide is carefully added, when the potassium compound of the phenol or phenol-carboxylic ester separates in crystalline form. The crystals are filtered off, washed with anhydrous ether, and decomposed with carbonic acid. The amount of phenol or ester set free can be determined by weight. If, in the case of small amounts, the alkali formed is to be determined titrimetrically, a considerable excess of potassium hydroxide should be avoided, otherwise it may occur that solid alkali as well as potassium phenylate may separate out.

In addition to these general methods several special methods are known which may here be described.

For the determination of thymol and carvaerol in volatile oils Kremers and Schreiner²⁾ have worked out a method. It is a modification of the method recommended by Messinger and Vortmann³⁾ and depends upon the property of these phenols to combine, in alkaline solution, with iodine to a red iodine thymol

¹⁾ Chem. Zeitschr. 2 (1903), 434.

²⁾ Pharm. Review 14 (1896), 221.

³⁾ Berl. Berichte 23 (1890), 2753.

compound which is precipitated. The excess of iodine, after acidulation of the liquid, can be titrated back with sodium thiosulphate solution. Every molecule of thymol, respectively carvacrol, requires 4 atoms of iodine for precipitation.

The process for thymol, which differs slightly from that for carvacrol, is as follows:

5 cc. of the oil to be assayed are weighed, transferred to a glass-stoppered burette that is calibrated into $\frac{1}{10}$ cc., and diluted with about an equal volume of petroleum ether. Five p. c. soda solution is added, the mixture well shaken and then allowed to separate. Complete separation having resulted, the alkaline solution is allowed to flow into a 100 cc. measuring flask and the shaking out with alkali solution repeated as often as a diminution of volume results.

The alkaline thymol solution is diluted with 5 p. c. sodium hydroxide solution to 100 cc. or, if necessary, to 200 cc.

To 10 cc. of this solution, transferred to a 500 cc. measuring flask, a slight excess of $\frac{N}{10}$ iodine solution is added causing the thymol to be precipitated as a dark brown iodine compound. In order to test whether sufficient iodine has been added, a few drops are transferred to a test tube and several drops of hydrochloric acid added. If a sufficient amount of iodine has been added, the solution is colored brown by free iodine, otherwise it becomes milky due to precipitated thymol. An excess of iodine having been added, the solution is acidified with dilute hydrochloric acid and diluted to 500 cc. In 100 cc. of the filtrate the excess of iodine is titrated by means of $\frac{N}{10}$ sodium thiosulphate solution.

The number of cc. of thiosulphate solution are deducted from the volume of iodine used and the resultant multiplied by five, this product indicating the total amount of iodine used by the thymol.

Each cc. of $\frac{N}{10}$ iodine solution consumed corresponds to 0.0037528 g. thymol.

From the amount of thymol found in the alkaline solution the percentage of phenol in the original oil can readily be computed.

The reaction can be expressed by means of the following equation:



In the assay of carvacrol a slight modification becomes necessary because the carvacrol iodide separates milky. In order to cause the formation of a precipitate the mixture is shaken thoroughly after the iodine has been added and then filtered. It is only then that the solution is acidified with hydrochloric acid. The process after that is the same as for thymol. The computation is likewise the same.

A method for the assay of eugenol in caraway oil has been suggested by Thoms.¹⁾ The method is based on the separation of eugenol as benzoyl eugenol. It enjoys the advantage that a melting point determination reveals identity as well as purity of the separated phenol. Somewhat later Thoms²⁾ modified this method by removing the sesquiterpenes, which interfere at times, before adding the benzoyl chloride. He enlarged upon it by taking into consideration the eugenol acetate occurring in the oil.

Assay of total eugenol. 5 g. of oil of cloves, contained in a 150 cc. beaker, are saponified with 20 g. of 15 p. c. caustic soda solution by heating on a water bath for half an hour. When still warm the contents of the beaker are transferred to a separating funnel with a short tube. After complete separation of the two layers, the solution of eugenol sodium is transferred back to the beaker. The sesquiterpenes remaining in the separating funnel are washed twice, each time with 5 cc. of 15 p. c. caustic soda solution and the lye in each case added to the eugenol sodium solution. 6 g. of benzoyl chloride are now added and the mixture shaken thoroughly until a uniform mixture has been obtained. In a few minutes the ester formation has taken place with appreciable rise of temperature. Any excess of benzoyl chloride is destroyed by brief heating on the water bath. After cooling 50 cc. of water are added, the mixture heated until the crystalline ester has been liquified, and again allowed to cool. The supernatant, clear liquid is removed by filtration, allowing the crystalline cake to remain in the beaker. Again 50 cc. of

¹⁾ Berichte d. deutsch. pharm. Ges. 1 (1891), 278.

²⁾ Arch. der Pharm. 241 (1903), 592.

water are added, heated on a water bath until the ester has melted, cooled and filtered. Finally, the ester is washed a third time in like manner with 50 cc. of water. The excess of caustic soda and sodium salts are then regarded as having been removed.

Any crystalline particles that have been caught in the filter are retransferred to the beaker. The benzoyl eugenol, while still moist, is dissolved in 25 cc. of alcohol (90 p. c. by weight) with the aid of the heat of the water bath and gentle agitation. Even after the beaker has been removed from the water bath, the shaking is continued until the benzoyl eugenol has crystallized out. This takes place within several minutes. The temperature of the mixture is lowered to 17°, the precipitate collected on a filter 9 cm. in diameter, and the filtrate collected in a graduated cylinder. About 20 cc. of filtrate are thus obtained. The alcoholic solution that has been retained by the crystalline magma in the filter is displaced by 90 p. c. (by weight) alcohol until the filtrate amounts to 25 ccm. The moist filter and precipitate are then transferred to a weighing dish (the latter together with the filter dried at 101° having been weighed previously), and dried at 101° until of constant weight. In as much as 25 cc. of 90 p. c. alcohol dissolve 0.55 g. of pure benzoyl eugenol at 17°, this amount should be added to the amount weighed.

If a stands for the amount of benzoic ester found, b for the amount of clove oil employed (about 5 g.), and if 25 cc. of alcoholic solution of ester are removed by filtration in accordance with the above directions, then the percentage of eugenol in clove oil is indicated by the formula

$$\frac{4100 \cdot (a + 0.55)}{67 \cdot b}$$

This formula results from the two equations:

(Benzoyl eugenol) (Eugenol)

$$268 : 164 :: (a + 0.55) : \text{the amount of eugenol found.}$$

$$\text{Eugenol} :: \frac{164 \cdot (a + 0.55)}{268}$$

$$\text{Hence } b : \frac{164 \cdot (a + 0.55)}{268} :: 100 : x.$$

$$x = \frac{164 \cdot (a + 0.55) \cdot 100}{268 \cdot b} = \frac{4100 \cdot (a + 0.55)}{67 \cdot b}$$

Assay of free eugenol. 5 g. of clove oil dissolved in 20 g. ether are quickly shaken out in a separating funnel with 20 g. of 15 p. c. caustic soda solution. The eugenol sodium solution is transferred to a beaker and the ethereal solution of sesquiterpenes is washed twice with 5 g. each of caustic soda solution of like strength. The united alkaline solutions are heated on a water bath for the purpose of driving off the ether and the benzoylation carried out in the manner described above.

Thus the free eugenol as well as that present as ester can be determined quantitatively. Thom's method can be applied equally well to other eugenol-containing oils provided they contain no free alcohols.

METHYL NUMBER.

A number of volatile oils contain as important constituents methyl and ethyl ethers of phenols and acids, the alkyl groups of which can be determined according to Zeisel's method.¹⁾ Benedikt and Grüssner²⁾ have recommended the quantitative methoxyl determination for the practical and scientific investigation of volatile oils, and have shown its usefulness by a series of illustrations. They designate as methyl number that number which tells how many mg. of methyl I g. of substance splits off when boiled with hydriodic acid. Ethyl or propyl and isopropyl are here considered as having been replaced by the equivalent amount of methyl. The weighed amount of silver iodide is therefore in all cases calculated as methyl.

The vapors of methyl iodide formed by boiling from 0.2 to 0.3 g. of the oil to be investigated with hydriodic acid (sp. gr. 1.70, to which, according to Herzig³⁾ 8% of acetic acid are added) are first passed through some warm water in which some phosphorus is suspended, so as to retain any iodine vapors which may have been carried over. After the methyl iodide has passed through this apparatus it is passed into an alcoholic solution of silver nitrate and the separated silver iodide weighed.

¹⁾ Monatsh. f. Chem. 6 (1885), 989.

²⁾ Chem. Ztg. 13 (1889), 872, 1087.

³⁾ Monatsh. f. Chem. 9 (1888), 544.

A very convenient apparatus has been designed by L. Elmann¹⁾ for carrying out this determination.

Gregor²⁾ has recently suggested to replace the phosphorus suspended in water by a solution of one part each of potassium bicarbonate and arsenous acid in 10 parts of water, by which not only the iodine vapors but also any hydriodic acid carried over is retained. For collecting the methyl iodide Gregor uses a $\frac{1}{10}$ normal silver nitrate solution which has been acidified with nitric acid and titrates back the silver not used for the precipitation of the silver iodide with $\frac{1}{10}$ normal potassium sulphocyanate solution according to Vollhard.

Of the oils investigated by Benedikt and Grüssner the following gave no methyl numbers: the oils of wormwood, bitter almond, angelica, bergamot, caraway, lemon, copaiba-balsam, coriander, cubeb, elemi, eucalyptus, geranium, juniper, cherry laurel, lavender, spearmint, peppermint, olibanum, oil of *Pinus montana*, saviu, East Indian and West Indian sandalwood, turpentine and valerian.

High methyl numbers were given by anise oil, star anise oil and fennel oil on account of their content of anethol and methyl chavicol, by clove oil, clove stem oil and oil of cinnamon leaves on account of their content of eugenol. In wintergreen oil the high methyl number is due to the methyl salicylate, in parsley oil to the apiol, and in calamus oil to its asarone³⁾ content.

The determination is applicable only to oils absolutely free from alcohol, as ethyl alcohol itself gives a methyl number, from which it follows, that this method may also be used for the quantitative estimation of alcohol in those oils which in their pure condition do not contain any methoxyl groups.⁴⁾

¹⁾ Description and illustration of the apparatus are to be found in Chem. Ztg. 14 (1890), 1767.

²⁾ Monatsh. f. Chem. 19 (1898), 116.

³⁾ Thoms and Beckström, Berl. Berichte 35 (1902), 3191.

⁴⁾ The methyl numbers of some of the oils examined by Benedikt and Grüssner can be explained only by assuming the presence of alcohol. It is to be regretted that the physical constants of the oils were not recorded so that some judgement might be passed on their purity. For the Ceylon cinnamon oil marked No. 22 in the paper of Benedikt and Grüssner they find 25.7 as methyl number and compute therefore a 28.1 p. c. eugenol content. In as much as pure Ceylon cinnamon oil contains only 4 to 8 p. c. eugenol, it would seem to follow (provided the methyl number found was due only

CINEOL DETERMINATION.

In addition to fractional distillation, several methods for the assay of cineol have been recommended. They all depend on the capacity of cineol to form addition products with certain other compounds. The description of the individual method is here given.

1. *Distillation method.*¹⁾ The oil to be examined is fractionated, fractions of two degrees each being collected, placed in a freezing mixture and their temperature reduced to -15 to -18° . Attempts are then made to cause them to congeal by shaking or by introducing a cineol crystal. After having stood in the freezing mixture for an hour, the liquid portion is drawn off by means of a pipette drawn out to a fine point. With some experience a well nigh dry mass of crystals can be obtained, from which the last traces of liquid can be removed by shaking the crystals. The liquified cineol of all fractions is united and weighed.

In as much as a portion of the cineol remains dissolved in the terpenes, all of the cineol is not obtained by this method. Hence the method is applicable only then when it is desired to ascertain which of a number of oils is richest in cineol.

2. *Hydrogen bromide method.* Into a solution of 10 cc. of oil in 40 cc. of low boiling petroleum ether (b. p. 35 to 40°), thoroughly chilled in a freezing mixture, absolutely dry hydrogen bromide is passed so long as a precipitate continues to be formed. The purely white cineol hydrobromide ($C_{10}H_{18}O \cdot HBr$) is quickly separated with the aid of a suction pump and washed with cold petroleum ether. Into the filtrate more hydrogen bromide is passed and, if additional precipitate results, this is collected separately and combined with the bulk of precipitate first obtained and separated.

to eugenol) that the oil had been adulterated with cinnamon leaf oil rich in eugenol. This example reveals that the methyl numbers reported should be adopted cautiously. It would be desirable indeed to repeat the determinations in connection with oils the purity of which has previously been established by other means. Only thus can desirable data be obtained which will give this method practical value. For the scientific investigation of volatile oils the methoxyl determination should prove exceedingly valuable since it reveals the presence or absence of phenol ethers or acid esters containing methyl, ethyl or propyl groups.

¹⁾ Helbing's Pharmacological Record No. VIII. London 1892.

In order to remove the petroleum ether, the cineol hydrobromide is left in a vacuum desiccator for a quarter of an hour. It is then transferred to a cassia flask with the aid of a little alcohol and decomposed with water. By the addition of more water the cineol is raised into the neck of the flask and its volume read off by means of the graduated scale. Multiplication with 10 yields the percentage of cineol by volume in the oil.

3. *Phosphoric acid method*,¹⁾ adopted by the U. S. Pharmacopœia, 8th decennial revision. To a solution of 10 cc. of oil in 50 cc. petroleum ether, which is thoroughly chilled in a freezing mixture, concentrated phosphoric acid is gradually added while stirring until the white precipitate ($C_{10}H_{18}O \cdot H_3PO_4$) attains a yellowish or reddish tint. The crystalline mass is removed with the aid of a force filter, washed with petroleum ether, dried by pressing between porous plates, and decomposed with water. The regenerated cineol is measured and the volume percentage computed.

Both the hydrobromic acid and phosphoric acid methods suffer from the drawback that their addition products with cineol are readily decomposable thus rendering difficult a quantitative separation. In consequence the results, as shown by Schimmel & Co.²⁾ in connection with trial assays of mixtures of known cineol content, are unreliable. In part they deviate very materially from the true composition. Nevertheless, the hydrogen bromide method may prove useful in cases where the cineol content is low since then all other methods fail.

4. *Resorcinol method*. Recently a method has been worked out in the laboratory of Schimmel & Co.³⁾ which depends on the

¹⁾ The method was first suggested by Helbing and Passmore who, however, employed no diluent. Helbing's Pharmacological Record No. XXIV. London 1893. Kebler attempted to introduce an improvement by titrating the phosphoric acid set free from the regenerated cineol after the cineol phosphate had been expressed. Americ. Journ. Pharm. 70 (1898), 492. If one, however, recalls how difficult it is to remove the sirupy phosphoric acid from the tough cineol phosphate cake, this change is not likely to enjoy the confidence of the analyst.

²⁾ Report of Schimmel & Co. October 1907, 47.

³⁾ Report of Schimmel & Co. October 1907, 47; Wiegand and Lehmann, Chem. Ztg. 32 (1908), 109; Report of Schimmel & Co. April 1908, 52.

property of cineol to form an addition product with resorcinol which is soluble in an excess of concentrated resorcinol solution. Method of procedure: To 10 cc. of oil contained in a 100 cc. cassia flask (fig. 75, p. 583) enough 50 p. c. resorcinol solution is added to fill the flask about four-fifths. For five minutes the mixture is thoroughly shaken, then that portion of the oil which has not gone into solution is driven into the neck with resorcinol solution. Any oily particles adhering to the walls of the flask are caused to rise to the surface by rotating the flask or gently tapping it. After the resorcinol solution has become perfectly clear, which usually requires several hours, the volume of oil remaining is read off, the cineol content ascertained by subtracting this amount from 10 and the resultant multiplied with 10 in order to obtain the percentage by volume. Oils very rich in cineol are advantageously diluted with an equal volume of turpentine oil since the cineolresorcinol occasionally crystallizes from concentrated solutions thus rendering futile the entire process.

The method as described above is to be applied only to such oils that contain no appreciable amounts of oxygenated compounds (alcohols, aldehydes) since resorcinol dissolves these also, thus causing the results to be too high. In all other cases the assay is carried out, not with the original oil but with the cineol fraction. For this purpose 100 cc. of oil are distilled from a Ladenburg fractionating flask with three bulbs (fig. 71, p. 566) at such a rate that a drop is collected each second. Fraction 170 to 190°, which contains all of the cineol of the oil, is collected separately and its volume ascertained. The cineol content of this fraction is then determined as described above and the percentage of cineol in the original oil computed. In the examination of mixtures of known cineol content, Wiegand and Lehmann have shown that the error is at most 2%.

If only small amounts of oil are available the method can be modified so as to separate the solid resorcinol compound and to decompose the latter. With some practice acceptable results can thus also be obtained though not with the same certainty as with the fractionation method just described. Nevertheless, it is preferable to the phosphoric acid addition method since the additionproduct of cineol with resorcinol is more stable than that with phosphoric acid.

10 cc. of oil are mixed with 20 cc. of a 50 p. c. resorcinol solution. If necessary, a crystal of cineol resorcinol is added and the resulting crystalline mass is stirred to form a uniform mixture. The crystalline mass is separated by means of a force filter, pressed between filter paper to remove the last traces of oil, and transferred to a beaker. Caustic alkali is then added, the mixture gently heated and the liquid transferred to a cassia flask by means of a funnel the tube of which passes to the bottom of the flask. The flask is finally filled to the mark, the amount of separated cineol read off and multiplied by 10 to obtain percentage by volume.

For the regeneration of the resorcinol used for these determinations steam is passed through the solution from which the non-cineol portions of the oil has been previously separated. The cineol distills over and the aqueous solution is evaporated for the recovery of the resorcinol which can be used again for another assay.

HYDROCYANIC ACID ASSAY.

The qualitative test for hydrogen cyanide has already been referred to on p. 533. Quantitatively it is best determined gravimetrically: About 1 g. of oil is accurately weighed and dissolved in 10 to 20 times its volume of alcohol. To this solution 10 cc. of alcoholic ammonia free from chlorine are added to decompose the phenylhydroxyacetonitrile since otherwise only a part of the hydrocyanic acid is determined.¹⁾ After standing for a short time an aqueous solution of silver nitrate is added and the mixture acidulated with nitric acid.²⁾ After the solution has become clear, the silver cyanide is collected on a filter, that has been previously dried and weighed, is carefully washed with water and dried at 100° until of constant weight. If *s* represents the number of grams of oil used, and *a* the number of grams

¹⁾ Kremers and Schreiner, Pharm. Review 14 (1896), 196.

²⁾ If much hydrogen cyanide be present, the addition of silver nitrate to the ammoniacal solution soon causes the precipitation of a finely crystalline precipitate of silver cyanide ammonia, NH_4AgCN . In order to prevent this the nitric acid should be added immediately after the addition of the silver nitrate solution.

of silver cyanide obtained, the percentage of hydrogen cyanide in the oil results from the following formula:

$$\% \text{ HCN} = \frac{a \cdot 20,179}{s}$$

More convenient, but less accurate, because the end reaction is ascertainable with difficulty and uncertainty, is the titrimetric method according to Viehhaber.¹⁾ Lichigs' method, which is frequently applied to bitter almond water, is not at all applicable to the oil.

The assay is carried out according to the following directions: About 1 g. of oil is weighed accurately and shaken with 10 cc. of water. In order to split up the cyanhydrin, some freshly precipitated magnesium hydroxide is added, then 2 to 3 drops of a 10 p. c. potassium chromate solution as indicator. While constantly shaking — in order to insure the intimate contact of the oil with the mixture — the titration is carried out by slowly adding $\frac{N}{10}$ silver nitrate solution until the red color of the silver chromate indicates the end of the reaction. Every cc. of $\frac{N}{10}$ silver nitrate solution corresponds to 0,0027018 g. of hydrocyanic acid. The percentage can be computed with the aid of the following formula:

$$\% \text{ HCN} = \frac{0,27018 \cdot b}{s}$$

in which b represents the number of cc. of $\frac{N}{10}$ silver nitrate solution and s the number of grams of oil used.

For practical purposes the titrimetric method may suffice. It has been adopted by the U. S. Pharmacopœia for the hydrocyanic acid assay of bitter almond oil. The U. S. P. gives 0,002684 as factor. The difference is due to the fact that the factor given above is based on $O = 16$ whereas the factor of the U. S. P. is based on $H = 1$.

Reference should here also be made to a critical discussion by Runne²⁾ of all gravimetric and volumetric methods for the determination of hydrocyanic acid in bitter almond water.

¹⁾ Arch. der Pharm. 213 (1878), 408.

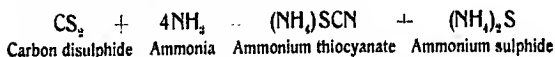
²⁾ Apotheker Ztg. 24 (1909), 288, 297, 306, 314, 325, 333, 344, 356.

MUSTARD OIL ASSAY.

Mustard oil can be assayed by weighing it as thiosinamine, or better by double decomposition with ammoniacal silver nitrate solution. In this case also thiosinamine is first obtained as intermediate product but, as soon as formed, it is decomposed with the precipitation of silver sulphide. According to the second method distinction is made between the gravimetric process (weighing of the precipitated silver sulphide) and the titrimetric process (in which $\frac{N}{10}$ silver nitrate solution is used and the excess of silver nitrate is titrated back). In actual practice the titrimetric method is used well nigh exclusively. For the sake of completeness, however, the other two methods are also described.

*Thiosinamine method.*¹⁾ If in a flask 3 g. of mustard oil and 3 g. of alcohol are shaken together with 6 g. of ammonia water the mixture becomes clear after standing several hours in the cold (quickly at 50°) and as a rule separates crystals of thiosinamine without coloration. The mother liquid having been separated from the crystals is evaporated in such a manner that only a part thereof is transferred to the evaporating dish on a water bath and new portions added only then when the odor of ammonia has disappeared. Finally the crystals are also transferred to the evaporating dish the last traces being transferred with the aid of a little alcohol. The dish is heated on the water bath until of constant weight. The 3.25 or at most 3.5 g. of thiosinamine (corresponding to from 92.6 to 100% of isothiocyan allyl) thus obtained constitute a brownish crystalline mass melting at 70° with a leek-like but by no means penetrating odor. It dissolves in 2 parts of warm water to a solution that does not change blue litmus paper, and possesses a bitter but not persistent taste.

It should be remembered, however, that any carbon disulphide present is likewise determined as thiosinamine, since with ammonia it undergoes the following reaction:



¹⁾ Direction according to the German Pharmacopœia, 3rd ed. 1890.

and since the resulting products remain largely behind upon evaporation. If the residue amounts to more than 3.5 g. an impermissible amount of carbon disulphide is very likely present, especially if it has the odor of ammonium sulphide.

The percentage of isothiocyanyl allyl can be computed with the aid of the formula:

$$\frac{a \cdot 85.34}{s}$$

in which a represents the amount of thiosinamine obtained and s the amount in grams of mustard oil used.

Kremel¹⁾ has suggested the use of ammonia of definite strength and to titrate back with half-normal hydrochloric acid the amount not used. No results of practical experience with this method appear to have been recorded.

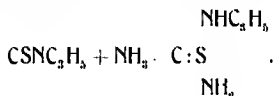
Determination with ammoniacal silver solution.

a) *Titrimetric method.* To about 5 g. (accurately weighed) of a solution of 1 g. mustard oil in 49 g. alcohol and contained in a 100 cc. measuring flask, 50 cc. of $\frac{N}{10}$ silver nitrate solution and 10 cc. ammonia water ($d_{15} 0.960$) are added; the flask, provided with a tube 1 meter long that serves as reflux condenser, and the mixture heated for 1 hour on a water bath that is in active circulation. After the temperature of the mixture has been reduced to that of the room, water is added to the 100 cc. mark, the contents shaken and filtered. To 50 cc. of the filtrate 6 cc. of nitric acid ($d_{15} 1.153$) and a few drops of ferric ammonium sulphate are added and titrated with ammonium thiocyanate until the red color remains permanent. In order to ascertain the total amount of silver solution that has entered into the reaction, the number of cc. of ammonium thiocyanate solution used should be multiplied by 2 and the product subtracted from 50. If s grams of the alcoholic solution of mustard oil have required a cc. of $\frac{N}{10}$ silver nitrate solution the percentage of isothiocyanyl allyl in the oil is

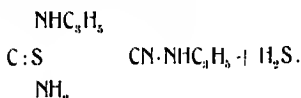
$$\frac{a \cdot 24.78}{s}$$

¹⁾ Pharm. Post 21 (1888), 828.

The reactions that take place can be represented by the following equations. First of all, the ammonia acts with the formation of thiosinamine:

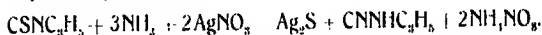


Ammoniacal silver nitrate breaks up this compound into allyl-cyanamide and sulphuretted hydrogen:



The sulphuretted hydrogen combines with the silver oxide to form silver sulphide.

The end reactions can be represented by the following empirical equation:



The principle of this method dates back to E. Dieterich¹⁾ who, however, suggested that the silver sulphide be weighed (see below). Gadamer²⁾ then modified the method by making it titrimetric. Following the directions of E. Dieterich the mixture was not heated but set aside for 24 hours. K. Dieterich³⁾ as well as Firbas⁴⁾ pointed out that the decomposition of the thiosinamine with silver nitrate is not complete even after 24 hours at room temperature and that accurate values are received only then when the mixture is heated for a short time after the period of standing. Kuntze⁵⁾ determined somewhat later that at room temperature more or less of the silver compound of allylsulpho-carbaminic acid ethylester is formed as well as silver sulphide. For every molecule of mustard oil this demands but one atom of silver, whereas the formation of silver sulphide demands two

¹⁾ Helffenberger *Annalen* 1840, 59.

²⁾ *Arch. der Pharm.* 237 (1899), 110. Comp. also *Arch. der Pharm.* 246 (1908), 59, footnote 2.

³⁾ *Pharm. Ztg.* 45 (1900), 768.

⁴⁾ *Zeitschr. d. allg. österr. Apoth. Ver.* 58 (1904), 222.

⁵⁾ *Arch. der Pharm.* 246 (1908), 58.

atoms of silver. The result is that less silver nitrate solution is used than is necessary for the complete decomposition, hence the results are too low.

The precipitation of thiourethane silver is avoided if the process is carried out at higher temperature. According to Kuntze the best results are obtained if the process is carried out as described above with the exception, however, that the mixture is immediately heated on a water bath for 1 hour. According to experiments made by Kuntze, the reduction of the silver solution when boiled with alcohol need not be feared.

b) *Gravimetric method.* As already pointed out, the method of determining the amount of *isothiocyanallyl* by means of ammoniacal silver solution was first suggested by E. Dieterich (*loc. cit.*), who, however, weighed the precipitated silver sulphide. Somewhat later K. Dieterich¹⁾ modified the method somewhat. One proceeds, first of all, as in the titrimetric method, but naturally it is not necessary to employ a standardized silver solution. After the precipitate has subsided, it is collected by passing the hot liquid through a filter that has previously been washed successively with ammonia, hot water, alcohol, and ether, dried and weighed. The collected precipitate is washed with hot water, the water displaced by strong alcohol and this in turn by ether. The precipitate thus treated is dried at about 80° until of constant weight. The percentage of *isothiocyanallyl* in the oil follows from the formula

$$\frac{a \cdot 39,995}{s}$$

in which a - the amount in grains of silver sulphide,

s - the amount in grams of mustard oil used.

According to Kuntze (*loc. cit.*) useful results are likewise obtained according to this method if the mixture is set aside at room temperature for 24 hours. Although, as previously indicated, thiourethane silver as well as silver sulphide may result, this affects the result but little, since the molecular weights of both compounds (248 and 252) are almost the same. As already pointed out, the side reaction may cause appreciable differences when proceeding according to the titrimetric method.

¹⁾ Helfenberger Annalen 1900, 182.

TEST FOR CHLORINE.

The test for chlorinated products is an important one in the examination of bitter almond oil, cherry laurel oil and a number of chemical preparations. In the case of the two oils mentioned, the test serves as a means to detect adulteration with common, technical benzaldehyde; in the case of chemical preparations it affords a clue as to their purity. The principal chemicals of this group are benzylalcohol, benzaldehyde, phenylacetaldehyde, cinnamic aldehyde, synthetic camphor, and benzyl acetate.

Socalled Beilstein test. A piece of copper oxide fastened to a platinum wire is moistened with the oil to be tested and held in the outer zone of a Bunsen flame. As soon as the carbon has burned away, the presence of chlorine is indicated by the greenish or greenish-blue color of the flame. This color is produced by volatilizing copper chloride and its intensity and duration depends on the amount of chlorine present.

Lime test. The oil to be tested is mixed intimately with about ten times its amount of burnt marble¹⁾ free from chlorine and the mixture heated to a low red heat in a crucible for a short time. Any chlorine that may be present combines with the calcium. The powder is dissolved in nitric acid and the filtered solution tested for chlorine in the ordinary manner.

Combustion method.²⁾ This method consists in burning the oil and testing the combustion products for hydrogen chloride. A piece of filter paper about 5 × 6 cm. is folded, saturated with the oil, the excess of oil thrown off, and the paper placed in a small porcelain capsule which in turn rests within a larger porcelain evaporating dish about 20 cm. in diameter. The paper is ignited and immediately covered with a beaker of 2 liter capacity the inner surface of which is moistened with water. The sizes of the implements should be so selected that the rim of the larger porcelain dish projects somewhat beyond that of the beaker. After the flame has become extinguished, the beaker

¹⁾ In place of the marble, calcined soda free from chlorine may be taken.

²⁾ Comp. Schimmel's Bericht April 1880, 99; also Report October 1904, 7.

is allowed to remain in its position for several minutes. The products of combustion which have condensed on the inner surface of the beaker are then washed into a filter with about 10 cc. of distilled water. The filtrate, rendered acid with a drop of nitric acid, should not be rendered turbid upon the addition of silver nitrate test solution.

This method has proven especially efficient in the testing of volatile oils. Even the minutest traces of chlorine compounds can thus be detected. For the sake of absolute certainty a blank test should be made with a pure oil, since deceptions may occur if the water and the impurities used have not been absolutely free from chlorine compounds. Compared with the lime test it has the advantage of being more convenient, especially if a large number of oils have to be tested.

In the case of oils containing hydrocyanic acid, deceptions may occur if unoxidized hydrogen cyanide is deposited on the inner surface of the beaker and washed out with the water. In such cases silver nitrate may produce a turbidity although the oil was pure. Such turbidity is due to AgCN and not to AgCl . This turbidity, however, differs from that produced by silver chloride in its disappearance when the liquid is heated carefully not quite to the boiling point.

Whereas the combustion method is much more delicate and reliable than Beilstein's method when applied to volatile oils, the latter is better adapted, according to Stephan,¹⁾ as a test for chlorine in artificial camphor.

The quantitative determination of chlorine can be carried out according to the well known method of Carius. A definite amount of oil is heated with fuming nitric acid in the presence of silver nitrate in a sealed tube and the silver chloride thus produced is weighed.

¹⁾ Comp. Lohmann, *Berichte d. deutsch. pharm. Ges.* 19 (1909), 222.

THE DETECTION OF SOME OF THE MORE COMMON ADULTERANTS.

TURPENTINE OIL.

Turpentine oil may be considered as the adulterant most often used. Very often it can be recognized by its characteristic odor, especially in those oils which contain no pinene, as this is the main constituent of turpentine oil. In general, its presence causes changes in the specific gravity, solubility, boiling temperature and optical rotation. It must here be remembered that there are dextro- as well as laevogyrate turpentine oils.

The positive proof of the presence of turpentine oil in oils, which in their pure state contain no pinene, is furnished by the isolation of and characteristic derivatives of pinene. The constituents boiling in the neighborhood of 160°, are fractionated out and, according to the method described on page 296, the pinene nitrosochloride, as well as pinene nitrobenzylamine or pinene nitropiperidine are prepared. If the fraction is strongly optically active, it is better to identify the pinene by oxidation to pinonic acid (see p. 297), for the yield of pinene nitrosochloride decreases as the optical activity of pinene increases.

If pinene is a normal constituent of the oil, the addition of turpentine oil can be recognized by a comparison of the physical properties of the lowest boiling fractions of the adulterated oil with the corresponding portions of the pure oil. The detection of turpentine oil in rosemary oil furnishes an example (see this).

CEDAR WOOD, COPAIBA AND GURJUN BALSAM OILS.

On account of their cheapness and faint odor, these three oils belong to the most favored and the most dangerous of adulterants. They may, however, be detected without difficulty in most cases by means of their physical properties, which differ from those of many of the volatile oils, namely their difficult solubility in 70 to 90 percent or even stronger alcohol, their high

specific gravity (above 0.900), their high boiling temperature, above 250° , and finally their rotatory power.

All three oils turn the plane of polarized light more or less to the left. With copaiba balsam oil the angle of rotation α_D lies between -7 and -35° ,¹⁾ with cedar wood oil between -25 and -44° , and with gurjun balsam oil between -35 and -130° (l).

At present only cedar wood oil and copaiba balsam oil can be detected in a chemical way. For this purpose the oil is subjected to fractional distillation and the fraction that passes over at about 260° examined. The cedrene contained in cedar wood oil can be oxidized in acetone solution with potassium permanganate to a glycol $C_{18}H_{26}O_2$ which melts at 160° , whereas caryophyllene can be characterized by means of its hydrate (m. p. 94 to 96, see p. 333 and 334). For the detection of gurjun balsam oil the observation of Deussen and Philipp²⁾ can possibly be utilized. If oxidized in acetone solution with potassium permanganate, the indifferent components yield a fraction 170 to 180° under 12 mm. pressure, which in turn yields a semicarbazone, $C_{18}H_{27}N_3O$, that melts at 234° .

ALCOHOL.

The addition of alcohol to a volatile oil always results in a lowering of the specific gravity. When an oil containing alcohol is dropped into water, the drops do not remain clear and transparent, as is the case with pure oils, but become opaque and milky.

For the definite identification of alcohol the suspected oil is heated until it just begins to boil,³⁾ and the first few drops that come over are collected in a test tube and filtered, to remove any oil globules which may also have come over, through a filter moistened with water. The filtrate is made strongly alkaline with dilute potassa solution, and treated, after heating to 50 to 60° ,

¹⁾ African copaiba balsam oils, the presence of which can be ascertained by the identification of cadinene (see p. 329), are dextrogyrate. According to the observations thus far recorded, the angle varies between $+16^{\circ}51'$ and $+22^{\circ}26'$. Dextrogyrate gurjunbalsam oils are also said to occur.

²⁾ Liebig's Annalen 369 (1909), 56.

³⁾ Not all of the alcohol is driven over by heating on the water bath.

with a solution of iodine in potassium iodide, until the solution remains slightly yellow. If alcohol is present small crystals of iodoform will separate in a short time at the bottom of the liquid. It must here be remembered that other bodies, such as aldehydes, acetone and acetic ether also yield iodoform under the conditions given.

Larger amounts of alcohol may be removed from volatile oils by shaking with water, from which the alcohol may be again removed by distillation and identified by the iodoform reaction. If the shaking out is done in a graduated cylinder, the increase of the aqueous layer corresponds approximately to the amount of the alcohol.

It is better, however, to use sodium chloride solution or glycerin, because with these the two layers separate better, and a more accurate reading is possible.

The alcohol content may also be approximately calculated if the specific gravity is determined before and after shaking with water.

If d is the specific gravity of the oil (at 15°),

D the specific gravity of the oil shaken with water, and

s the specific gravity of the alcohol,¹⁾

the alcohol content of the oil in percent follows from the formula

$$\frac{(D-d) \cdot 100}{D-s}$$

As already mentioned on page 599 the amount of the alcohol in an oil which in itself does not give a methyl number, may be determined quantitatively by Zeisel's methoxyl method.

FATTY OIL.

The volatile oils adulterated with fatty oil leave a permanent fatty stain when evaporated on paper. With high boiling and difficultly volatile oils, however, similar residues are left, which may give rise to mistakes. Fatty oil is insoluble in 90 percent alcohol.²⁾ For the separation of the fatty oil from the volatile

¹⁾ The specific gravities of alcohols of varying strengths are given on p. 568.

²⁾ Castor oil only is soluble in 90 p. c. alcohol, but is insoluble in 70 p. c. alcohol and in petroleum ether. Mention should also be made of the slight optical activity of castor oil, α_D about $+5^\circ$.

oil, the latter is distilled off by steam distillation or removed by evaporation in an open dish on the water bath. However, it should be remembered that some volatile oils, such as bergamot, lemon, orange, anise and star-anise oil, leave a residue of several percent even when they are not adulterated. This is also true of resinified oils.

The presence of the fat may be shown qualitatively in the residue by heating with potassium bisulphate in a test tube. Penetrating odors of acrolein show its presence. By igniting the residue on a platinum foil the characteristic odor of burning fat is noticed.

As the fatty oils give saponification numbers which lie between 180 and 200, the amount of the fat added can be determined quantitatively by saponification either directly in the volatile oil itself or in the distillation residue.

Oils that have been adulterated with cocoa nut oil solidify wholly or in part in a freezing mixture. Cocoa nut oil has been found in cananga oil, citronella oil and palmarosa oil and detected in this manner.

MINERAL OIL, PETROLEUM.

Mineral oil, paraffin oil, kerosene, petroleum and petroleum fractions are insoluble in alcohol and can therefore be detected without difficulty in volatile oils; besides, they are often easily recognized by their low specific gravity. Palmarosa oil to which some mineral oil has been added is only partly soluble in 70 percent alcohol. If the insoluble portion is successively treated with 90 percent and absolute alcohol, an oil remains, which in the beginning it is true is colored brown by sulphuric or nitric acids, but in general resists the action of these acids and also of alkalies, and on saponification with alcoholic potassa gives no saponification number.

The mineral oils have different boiling points. The hydrocarbons of illuminating oil boil at about the same temperature as the terpenes. Lower boiling fractions are said to be sometimes used for adulterating turpentine oil. A higher boiling mineral oil, about 250°, has been found in citronella and in gingergrass oils. The petroleum fractions of lower boiling temperatures are

easily volatile with water vapor, the higher fractions not at all, or at least to a small degree only.

A method for the quantitative estimation of mineral oils consists in weighing the residue left after having removed the volatile oil by oxidation with fuming nitric acid, as described under turpentine oil. According to Herzfeld¹⁾ concentrated sulphuric acid is better adapted to the separation of mineral oil than nitric acid. However, the investigators are very much divided in their opinions on this subject. (For details see under turpentine oil in the second volume). Attention should be called to the fact that some volatile oils, such as rose oil, chamomile oil, orange flower oil and others, contain larger or smaller amounts of paraffins as natural constituents.

CHLOROFORM.

This body, which has been found occasionally in volatile oils (for instance, in cognac oil), can be isolated by distillation on a water bath and identified by the isonitrile reaction. This consists in that a small amount of the suspected distillate is treated with a few drops of aniline and alcoholic caustic soda solution, and gently heated. In the presence of chloroform the noxious and exceedingly disagreeable smelling vapors of phenyl-isonitrile are formed.

ADDITIONS TO INCREASE THE ESTER CONTENT.

The valuation of such oils as bergamot and lavender according to their ester content has led to the occasional adulteration of such oils with cheaper esters or organic acids for the purpose of increasing their apparent ester content. Among the substances added for this purpose the following have been observed thus far: benzoic acid, salicylic acid, oleic acid, diethylsuccinate, triethylcitrate, glycerylmonacetate, ethyltartrate and terpinylacetate.

The presence of acids can be detected by means of an increase in the acid value, which, in most oils, is very small. For this reason the advice was given on p. 571 to determine

¹⁾ Zeitschr. f. öff. Chem. 9 (1903), 454. Comp. Chem. Zentralbl. 1904, I, 548.

the acid value and the ester value separately. The acids can be isolated by shaking the oil containing them with dilute soda solution, separating the latter and decomposing the salt formed with a mineral acid.

The identification of the esters may be carried out in various ways. In most instances the oil is fractionated, the fraction to be examined saponified, and the attempt made to characterize the components. However, special methods are also employed varying with the kind of ester. Thus *e. g.* fractional saponification may lead to the detection of added terpinyl acetate. In consequence of the high specific gravity of the esters used for adulteration, such adulterated oils become suspicious in many instances because of their increased density. Details as to such adulterations will be found in the second volume under the respective oils.

Table I

for Calculating the Percentage Content of Alcohols of the Formulas $C_{10}H_{18}O$, $C_{10}H_{20}O$, $C_{16}H_{24}O$ and $C_{16}H_{26}O$ from the Saponification Values before and after Acetylation, also the Percentage Content of the Acetic Esters of these Alcohols.

Table II

for Determining the Ester Value (Acid Value, Saponification Value), also the Percentage Content of Alcohol and Ester directly from the Number of cc. $\frac{n}{2}$ Potassium Hydroxide when 1.50 g. of Oil are used.

T

for Calculating the Percentage Content of Alcohols of the For
before and after Acetylation, also the Perce

| E. V. | $C_{10}H_{18}O$ | | | $C_{10}H_{20}O$ | | | E. V. |
|-------|-----------------|---------|-----------------------------|-----------------|---------|-----------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 1 | 0,35 | 0,28 | 0,28 | 0,35 | 0,28 | 0,28 | 1 |
| 2 | 0,70 | 0,55 | 0,55 | 0,71 | 0,56 | 0,56 | 2 |
| 3 | 1,05 | 0,83 | 0,83 | 1,06 | 0,84 | 0,84 | 3 |
| 4 | 1,40 | 1,10 | 1,10 | 1,41 | 1,11 | 1,12 | 4 |
| 5 | 1,75 | 1,38 | 1,38 | 1,77 | 1,39 | 1,40 | 5 |
| 6 | 2,10 | 1,65 | 1,66 | 2,12 | 1,67 | 1,68 | 6 |
| 7 | 2,45 | 1,93 | 1,94 | 2,47 | 1,95 | 1,96 | 7 |
| 8 | 2,80 | 2,20 | 2,21 | 2,83 | 2,23 | 2,24 | 8 |
| 9 | 3,15 | 2,48 | 2,49 | 3,18 | 2,51 | 2,52 | 9 |
| 10 | 3,50 | 2,75 | 2,77 | 3,54 | 2,79 | 2,81 | 10 |
| 11 | 3,85 | 3,03 | 3,05 | 3,89 | 3,06 | 3,09 | 11 |
| 12 | 4,20 | 3,30 | 3,33 | 4,24 | 3,34 | 3,37 | 12 |
| 13 | 4,55 | 3,58 | 3,61 | 4,60 | 3,62 | 3,66 | 13 |
| 14 | 4,90 | 3,85 | 3,89 | 4,95 | 3,90 | 3,94 | 14 |
| 15 | 5,25 | 4,13 | 4,17 | 5,30 | 4,18 | 4,23 | 15 |
| 16 | 5,60 | 4,40 | 4,45 | 5,66 | 4,46 | 4,51 | 16 |
| 17 | 5,95 | 4,68 | 4,74 | 6,01 | 4,74 | 4,80 | 17 |
| 18 | 6,30 | 4,95 | 5,02 | 6,36 | 5,01 | 5,08 | 18 |
| 19 | 6,65 | 5,23 | 5,30 | 6,72 | 5,29 | 5,37 | 19 |
| 20 | 7,00 | 5,50 | 5,58 | 7,07 | 5,57 | 5,66 | 20 |
| 21 | 7,35 | 5,78 | 5,87 | 7,42 | 5,85 | 5,94 | 21 |
| 22 | 7,70 | 6,05 | 6,15 | 7,78 | 6,13 | 6,23 | 22 |
| 23 | 8,05 | 6,33 | 6,44 | 8,13 | 6,41 | 6,52 | 23 |
| 24 | 8,40 | 6,60 | 6,72 | 8,49 | 6,69 | 6,81 | 24 |
| 25 | 8,75 | 6,88 | 7,01 | 8,84 | 6,96 | 7,10 | 25 |
| 26 | 9,10 | 7,15 | 7,29 | 9,19 | 7,24 | 7,39 | 26 |
| 27 | 9,45 | 7,43 | 7,58 | 9,55 | 7,52 | 7,68 | 27 |
| 28 | 9,80 | 7,70 | 7,87 | 9,90 | 7,80 | 7,97 | 28 |
| 29 | 10,15 | 7,98 | 8,15 | 10,25 | 8,08 | 8,26 | 29 |
| 30 | 10,50 | 8,25 | 8,44 | 10,61 | 8,36 | 8,55 | 30 |

D, $C_{10}H_{20}O$, $C_{18}H_{34}O$ and $C_{18}H_{36}O$, from the Saponification Values
t of the Acetic Esters of these Alcohols.

| I. V. | $C_{17}H_{34}O$ | | | $C_{15}H_{30}O$ | | | E. V. |
|-------|-----------------|---------|-----------------------------|-----------------|---------|-----------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 1 | 0,47 | 0,39 | 0,39 | 0,47 | 0,40 | 0,40 | 1 |
| 2 | 0,94 | 0,79 | 0,79 | 0,94 | 0,79 | 0,79 | 2 |
| 3 | 1,40 | 1,18 | 1,18 | 1,41 | 1,19 | 1,19 | 3 |
| 4 | 1,87 | 1,57 | 1,58 | 1,89 | 1,59 | 1,59 | 4 |
| 5 | 2,34 | 1,96 | 1,97 | 2,36 | 1,98 | 1,99 | 5 |
| 6 | 2,81 | 2,36 | 2,37 | 2,83 | 2,38 | 2,39 | 6 |
| 7 | 3,28 | 2,75 | 2,76 | 3,30 | 2,78 | 2,79 | 7 |
| 8 | 3,74 | 3,14 | 3,16 | 3,77 | 3,17 | 3,19 | 8 |
| 9 | 4,21 | 3,53 | 3,56 | 4,24 | 3,57 | 3,59 | 9 |
| 10 | 4,68 | 3,93 | 3,96 | 4,71 | 3,96 | 3,99 | 10 |
| 11 | 5,15 | 4,32 | 4,36 | 5,19 | 4,36 | 4,40 | 11 |
| 12 | 5,61 | 4,71 | 4,76 | 5,66 | 4,76 | 4,80 | 12 |
| 13 | 6,08 | 5,11 | 5,16 | 6,13 | 5,15 | 5,20 | 13 |
| 14 | 6,55 | 5,50 | 5,56 | 6,60 | 5,55 | 5,61 | 14 |
| 15 | 7,02 | 5,89 | 5,96 | 7,07 | 5,95 | 6,01 | 15 |
| 16 | 7,49 | 6,29 | 6,36 | 7,54 | 6,34 | 6,42 | 16 |
| 17 | 7,95 | 6,68 | 6,77 | 8,01 | 6,74 | 6,83 | 17 |
| 18 | 8,42 | 7,07 | 7,17 | 8,49 | 7,14 | 7,23 | 18 |
| 19 | 8,89 | 7,46 | 7,57 | 8,96 | 7,53 | 7,64 | 19 |
| 20 | 9,36 | 7,86 | 7,98 | 9,43 | 7,93 | 8,05 | 20 |
| 21 | 9,83 | 8,25 | 8,38 | 9,90 | 8,33 | 8,46 | 21 |
| 22 | 10,29 | 8,64 | 8,79 | 10,37 | 8,72 | 8,87 | 22 |
| 23 | 10,76 | 9,03 | 9,19 | 10,84 | 9,12 | 9,28 | 23 |
| 24 | 11,23 | 9,42 | 9,60 | 11,31 | 9,51 | 9,69 | 24 |
| 25 | 11,70 | 9,82 | 10,01 | 11,79 | 9,91 | 10,10 | 25 |
| 26 | 12,16 | 10,21 | 10,42 | 12,26 | 10,30 | 10,51 | 26 |
| 27 | 12,63 | 10,60 | 10,83 | 12,73 | 10,70 | 10,92 | 27 |
| 28 | 13,10 | 11,00 | 11,24 | 13,20 | 11,10 | 11,34 | 28 |
| 29 | 13,57 | 11,39 | 11,65 | 13,67 | 11,49 | 11,75 | 29 |
| 30 | 14,04 | 11,79 | 12,06 | 14,14 | 11,89 | 12,17 | 30 |

Table I

| E. V. | $C_{10}H_{18}O$ | | | $C_{10}H_{20}O$ | | | E. V. |
|-------|-----------------|---------|--------------------------|-----------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 31 | 10,85 | 8,53 | 8,73 | 10,96 | 8,64 | 8,84 | 31 |
| 32 | 11,20 | 8,80 | 9,02 | 11,31 | 8,91 | 9,13 | 32 |
| 33 | 11,55 | 9,08 | 9,31 | 11,67 | 9,19 | 9,43 | 33 |
| 34 | 11,90 | 9,35 | 9,59 | 12,02 | 9,47 | 9,72 | 34 |
| 35 | 12,25 | 9,63 | 9,88 | 12,37 | 9,75 | 10,01 | 35 |
| 36 | 12,60 | 9,90 | 10,17 | 12,73 | 10,03 | 10,31 | 36 |
| 37 | 12,95 | 10,18 | 10,47 | 13,08 | 10,31 | 10,60 | 37 |
| 38 | 13,30 | 10,45 | 10,76 | 13,44 | 10,59 | 10,90 | 38 |
| 39 | 13,65 | 10,73 | 11,05 | 13,79 | 10,86 | 11,19 | 39 |
| 40 | 14,00 | 11,00 | 11,34 | 14,14 | 11,14 | 11,49 | 40 |
| 41 | 14,35 | 11,28 | 11,63 | 14,50 | 11,42 | 11,78 | 41 |
| 42 | 14,70 | 11,55 | 11,93 | 14,85 | 11,70 | 12,08 | 42 |
| 43 | 15,05 | 11,83 | 12,22 | 15,20 | 11,98 | 12,38 | 43 |
| 44 | 15,40 | 12,10 | 12,51 | 15,56 | 12,26 | 12,68 | 44 |
| 45 | 15,75 | 12,38 | 12,81 | 15,91 | 12,54 | 12,97 | 45 |
| 46 | 16,10 | 12,65 | 13,10 | 16,26 | 12,81 | 13,27 | 46 |
| 47 | 16,45 | 12,93 | 13,40 | 16,62 | 13,09 | 13,57 | 47 |
| 48 | 16,80 | 13,20 | 13,69 | 16,97 | 13,37 | 13,87 | 48 |
| 49 | 17,15 | 13,48 | 13,99 | 17,32 | 13,65 | 14,17 | 49 |
| 50 | 17,50 | 13,75 | 14,29 | 17,68 | 13,93 | 14,47 | 50 |
| 51 | 17,85 | 14,03 | 14,58 | 18,03 | 14,21 | 14,77 | 51 |
| 52 | 18,20 | 14,30 | 14,88 | 18,39 | 14,49 | 15,07 | 52 |
| 53 | 18,55 | 14,58 | 15,18 | 18,74 | 14,76 | 15,38 | 53 |
| 54 | 18,90 | 14,85 | 15,48 | 19,09 | 15,04 | 15,68 | 54 |
| 55 | 19,25 | 15,13 | 15,77 | 19,45 | 15,32 | 15,98 | 55 |
| 56 | 19,60 | 15,40 | 16,07 | 19,80 | 15,60 | 16,28 | 56 |
| 57 | 19,95 | 15,68 | 16,38 | 20,15 | 15,88 | 16,59 | 57 |
| 58 | 20,30 | 15,95 | 16,68 | 20,51 | 16,16 | 16,89 | 58 |
| 59 | 20,65 | 16,23 | 16,98 | 20,86 | 16,44 | 17,20 | 59 |
| 60 | 21,00 | 16,50 | 17,28 | 21,21 | 16,71 | 17,50 | 60 |
| 61 | 21,35 | 16,78 | 17,58 | 21,57 | 16,99 | 17,81 | 61 |
| 62 | 21,70 | 17,05 | 17,88 | 21,92 | 17,27 | 18,11 | 62 |
| 63 | 22,05 | 17,33 | 18,18 | 22,27 | 17,55 | 18,42 | 63 |
| 64 | 22,40 | 17,60 | 18,49 | 22,63 | 17,83 | 18,73 | 64 |
| 65 | 22,75 | 17,88 | 18,79 | 22,98 | 18,11 | 19,04 | 65 |
| 66 | 23,10 | 18,15 | 19,10 | 23,34 | 18,39 | 19,34 | 66 |
| 67 | 23,45 | 18,43 | 19,40 | 23,69 | 18,66 | 19,65 | 67 |
| 68 | 23,80 | 18,70 | 19,70 | 24,04 | 18,94 | 19,96 | 68 |
| 69 | 24,15 | 18,98 | 20,01 | 24,40 | 19,22 | 20,27 | 69 |
| 70 | 24,50 | 19,25 | 20,32 | 24,75 | 19,50 | 20,58 | 70 |

Table I

| E. V. | $C_{15}H_{34}O$ | | | $C_{16}H_{36}O$ | | | E. V. |
|-------|-----------------|---------|--------------------------|-----------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 31 | 14,51 | 12,18 | 12,47 | 14,61 | 12,28 | 12,58 | 31 |
| 32 | 14,98 | 12,57 | 12,88 | 15,08 | 12,68 | 13,00 | 32 |
| 33 | 15,45 | 12,96 | 13,29 | 15,55 | 13,08 | 13,41 | 33 |
| 34 | 15,91 | 13,35 | 13,71 | 16,02 | 13,48 | 13,83 | 34 |
| 35 | 16,38 | 13,75 | 14,12 | 16,50 | 13,88 | 14,25 | 35 |
| 36 | 16,85 | 14,14 | 14,54 | 16,97 | 14,27 | 14,67 | 36 |
| 37 | 17,32 | 14,54 | 14,95 | 17,44 | 14,66 | 15,09 | 37 |
| 38 | 17,79 | 14,93 | 15,37 | 17,91 | 15,06 | 15,51 | 38 |
| 39 | 18,25 | 15,32 | 15,78 | 18,38 | 15,46 | 15,93 | 39 |
| 40 | 18,71 | 15,71 | 16,20 | 18,86 | 15,86 | 16,35 | 40 |
| 41 | 19,18 | 16,10 | 16,62 | 19,33 | 16,25 | 16,77 | 41 |
| 42 | 19,65 | 16,50 | 17,04 | 19,80 | 16,65 | 17,19 | 42 |
| 43 | 20,12 | 16,89 | 17,46 | 20,27 | 17,05 | 17,61 | 43 |
| 44 | 20,59 | 17,28 | 17,88 | 20,74 | 17,44 | 18,04 | 44 |
| 45 | 21,05 | 17,68 | 18,30 | 21,21 | 17,84 | 18,46 | 45 |
| 46 | 21,52 | 18,07 | 18,72 | 21,69 | 18,24 | 18,89 | 46 |
| 47 | 21,99 | 18,46 | 19,14 | 22,16 | 18,63 | 19,32 | 47 |
| 48 | 22,46 | 18,85 | 19,56 | 22,63 | 19,03 | 19,74 | 48 |
| 49 | 22,93 | 19,25 | 19,98 | 23,10 | 19,43 | 20,17 | 49 |
| 50 | 23,39 | 19,64 | 20,41 | 23,57 | 19,82 | 20,59 | 50 |
| 51 | 23,86 | 20,03 | 20,83 | 24,04 | 20,22 | 21,02 | 51 |
| 52 | 24,33 | 20,42 | 21,26 | 24,51 | 20,62 | 21,45 | 52 |
| 53 | 24,80 | 20,82 | 21,68 | 24,99 | 21,01 | 21,88 | 53 |
| 54 | 25,26 | 21,21 | 22,11 | 25,46 | 21,41 | 22,31 | 54 |
| 55 | 25,73 | 21,60 | 22,54 | 25,93 | 21,81 | 22,74 | 55 |
| 56 | 26,20 | 22,00 | 22,96 | 26,40 | 22,20 | 23,17 | 56 |
| 57 | 26,67 | 22,39 | 23,39 | 26,87 | 22,60 | 23,61 | 57 |
| 58 | 27,14 | 22,78 | 23,82 | 27,34 | 23,00 | 24,04 | 58 |
| 59 | 27,61 | 23,17 | 24,25 | 27,81 | 23,39 | 24,47 | 59 |
| 60 | 28,07 | 23,57 | 24,68 | 28,29 | 23,79 | 24,91 | 60 |
| 61 | 28,54 | 23,96 | 25,11 | 28,76 | 24,19 | 25,34 | 61 |
| 62 | 29,01 | 24,35 | 25,54 | 29,23 | 24,58 | 25,77 | 62 |
| 63 | 29,48 | 24,75 | 25,97 | 29,70 | 24,98 | 26,21 | 63 |
| 64 | 29,95 | 25,14 | 26,41 | 30,17 | 25,38 | 26,65 | 64 |
| 65 | 30,41 | 25,53 | 26,84 | 30,64 | 25,77 | 27,09 | 65 |
| 66 | 30,88 | 25,93 | 27,27 | 31,11 | 26,17 | 27,53 | 66 |
| 67 | 31,35 | 26,32 | 27,71 | 31,59 | 26,57 | 27,97 | 67 |
| 68 | 31,81 | 26,71 | 28,14 | 32,06 | 26,96 | 28,41 | 68 |
| 69 | 32,28 | 27,10 | 28,58 | 32,53 | 27,35 | 28,85 | 69 |
| 70 | 32,75 | 27,50 | 29,02 | 33,00 | 27,75 | 29,29 | 70 |

Table I

| E. V. | C ₁₀ H ₁₈ O | | | C ₁₀ H ₁₆ O | | | E. V. |
|-------|-----------------------------------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 71 | 24,85 | 19,53 | 20,62 | 25,10 | 19,78 | 20,89 | 71 |
| 72 | 25,20 | 19,80 | 20,93 | 25,46 | 20,06 | 21,20 | 72 |
| 73 | 25,55 | 20,08 | 21,24 | 25,81 | 20,34 | 21,51 | 73 |
| 74 | 25,90 | 20,35 | 21,55 | 26,16 | 20,61 | 21,83 | 74 |
| 75 | 26,25 | 20,63 | 21,85 | 26,52 | 20,89 | 22,14 | 75 |
| 76 | 26,60 | 20,90 | 22,16 | 26,87 | 21,17 | 22,45 | 76 |
| 77 | 26,95 | 21,18 | 22,47 | 27,22 | 21,45 | 22,77 | 77 |
| 78 | 27,30 | 21,45 | 22,78 | 27,58 | 21,73 | 23,08 | 78 |
| 79 | 27,65 | 21,73 | 23,09 | 27,93 | 22,01 | 23,39 | 79 |
| 80 | 28,00 | 22,00 | 23,40 | 28,29 | 22,29 | 23,71 | 80 |
| 81 | 28,35 | 22,28 | 23,72 | 28,64 | 22,56 | 24,02 | 81 |
| 82 | 28,70 | 22,55 | 24,03 | 28,99 | 22,84 | 24,34 | 82 |
| 83 | 29,05 | 22,83 | 24,34 | 29,35 | 23,12 | 24,66 | 83 |
| 84 | 29,40 | 23,10 | 24,65 | 29,70 | 23,40 | 24,97 | 84 |
| 85 | 29,75 | 23,38 | 24,97 | 30,05 | 23,68 | 25,29 | 85 |
| 86 | 30,10 | 23,65 | 25,28 | 30,41 | 23,96 | 25,61 | 86 |
| 87 | 30,45 | 23,93 | 25,60 | 30,76 | 24,24 | 25,93 | 87 |
| 88 | 30,80 | 24,20 | 25,91 | 31,11 | 24,51 | 26,25 | 88 |
| 89 | 31,15 | 24,48 | 26,23 | 31,47 | 24,79 | 26,57 | 89 |
| 90 | 31,50 | 24,75 | 26,54 | 31,82 | 25,07 | 26,89 | 90 |
| 91 | 31,85 | 25,03 | 26,86 | 32,17 | 25,35 | 27,21 | 91 |
| 92 | 32,20 | 25,30 | 27,18 | 32,53 | 25,63 | 27,53 | 92 |
| 93 | 32,55 | 25,58 | 27,49 | 32,88 | 25,91 | 27,85 | 93 |
| 94 | 32,90 | 25,85 | 27,81 | 33,24 | 26,19 | 28,17 | 94 |
| 95 | 33,25 | 26,13 | 28,13 | 33,59 | 26,46 | 28,49 | 95 |
| 96 | 33,60 | 26,40 | 28,45 | 33,94 | 26,74 | 28,82 | 96 |
| 97 | 33,95 | 26,68 | 28,77 | 34,30 | 27,02 | 29,14 | 97 |
| 98 | 34,30 | 26,95 | 29,09 | 34,65 | 27,30 | 29,47 | 98 |
| 99 | 34,65 | 27,23 | 29,41 | 35,00 | 27,58 | 29,79 | 99 |
| 100 | 35,00 | 27,50 | 29,73 | 35,36 | 27,86 | 30,11 | 100 |
| 101 | 35,35 | 27,78 | 30,05 | 35,71 | 28,14 | 30,44 | 101 |
| 102 | 35,70 | 28,05 | 30,37 | 36,06 | 28,41 | 30,77 | 102 |
| 103 | 36,05 | 28,33 | 30,70 | 36,42 | 28,69 | 31,09 | 103 |
| 104 | 36,40 | 28,60 | 31,02 | 36,77 | 28,97 | 31,42 | 104 |
| 105 | 36,75 | 28,88 | 31,34 | 37,12 | 29,25 | 31,75 | 105 |
| 106 | 37,10 | 29,15 | 31,67 | 37,48 | 29,53 | 32,08 | 106 |
| 107 | 37,45 | 29,43 | 31,99 | 37,83 | 29,81 | 32,41 | 107 |
| 108 | 37,80 | 29,70 | 32,32 | 38,19 | 30,09 | 32,74 | 108 |
| 109 | 38,15 | 29,98 | 32,64 | 38,54 | 30,36 | 33,07 | 109 |
| 110 | 38,50 | 30,25 | 32,97 | 38,89 | 30,64 | 33,40 | 110 |

Table I

| F. V. | $C_{15}H_{24}O$ | | | $C_{15}H_{26}O$ | | | F. V. |
|-------|-----------------|---------|--------------------------|-----------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 71 | 33,22 | 27,89 | 29,46 | 33,47 | 28,15 | 29,73 | 71 |
| 72 | 33,69 | 28,28 | 29,90 | 33,94 | 28,54 | 30,17 | 72 |
| 73 | 34,15 | 28,67 | 30,34 | 34,41 | 28,94 | 30,61 | 73 |
| 74 | 34,62 | 29,07 | 30,78 | 34,89 | 29,34 | 31,06 | 74 |
| 75 | 35,09 | 29,46 | 31,22 | 35,36 | 29,73 | 31,50 | 75 |
| 76 | 35,56 | 29,85 | 31,66 | 35,83 | 30,13 | 31,95 | 76 |
| 77 | 36,03 | 30,25 | 32,10 | 36,30 | 30,53 | 32,40 | 77 |
| 78 | 36,49 | 30,64 | 32,54 | 36,77 | 30,92 | 32,84 | 78 |
| 79 | 36,96 | 31,03 | 32,98 | 37,24 | 31,31 | 33,29 | 79 |
| 80 | 37,43 | 31,43 | 33,43 | 37,71 | 31,71 | 33,74 | 80 |
| 81 | 37,90 | 31,82 | 33,87 | 38,19 | 32,11 | 34,19 | 81 |
| 82 | 38,37 | 32,21 | 34,32 | 38,66 | 32,50 | 34,64 | 82 |
| 83 | 38,84 | 32,60 | 34,77 | 39,13 | 32,90 | 35,09 | 83 |
| 84 | 39,30 | 33,00 | 35,22 | 39,60 | 33,30 | 35,54 | 84 |
| 85 | 39,77 | 33,39 | 35,66 | 40,07 | 33,69 | 35,99 | 85 |
| 86 | 40,24 | 33,78 | 36,11 | 40,54 | 34,09 | 36,44 | 86 |
| 87 | 40,70 | 34,18 | 36,56 | 41,01 | 34,49 | 36,90 | 87 |
| 88 | 41,17 | 34,57 | 37,01 | 41,49 | 34,88 | 37,35 | 88 |
| 89 | 41,64 | 34,96 | 37,46 | 41,96 | 35,28 | 37,80 | 89 |
| 90 | 42,11 | 35,36 | 37,92 | 42,43 | 35,68 | 38,26 | 90 |
| 91 | 42,57 | 35,75 | 38,37 | 42,90 | 36,08 | 38,71 | 91 |
| 92 | 43,04 | 36,14 | 38,82 | 43,37 | 36,47 | 39,17 | 92 |
| 93 | 43,51 | 36,53 | 39,27 | 43,84 | 36,87 | 39,63 | 93 |
| 94 | 43,98 | 36,92 | 39,73 | 44,31 | 37,26 | 40,09 | 94 |
| 95 | 44,45 | 37,32 | 40,18 | 44,79 | 37,66 | 40,55 | 95 |
| 96 | 44,92 | 37,71 | 40,64 | 45,26 | 38,05 | 41,01 | 96 |
| 97 | 45,39 | 38,10 | 41,10 | 45,73 | 38,45 | 41,47 | 97 |
| 98 | 45,85 | 38,50 | 41,55 | 46,20 | 38,85 | 41,93 | 98 |
| 99 | 46,32 | 38,89 | 42,01 | 46,67 | 39,24 | 42,39 | 99 |
| 100 | 46,79 | 39,29 | 42,47 | 47,14 | 39,64 | 42,86 | 100 |
| 101 | 47,26 | 39,68 | 42,93 | 47,61 | 40,04 | 43,32 | 101 |
| 102 | 47,72 | 40,07 | 43,39 | 48,09 | 40,43 | 43,78 | 102 |
| 103 | 48,19 | 40,46 | 43,85 | 48,56 | 40,83 | 44,24 | 103 |
| 104 | 48,66 | 40,85 | 44,32 | 49,03 | 41,23 | 44,71 | 104 |
| 105 | 49,13 | 41,25 | 44,78 | 49,50 | 41,63 | 45,18 | 105 |
| 106 | 49,59 | 41,64 | 45,24 | 49,97 | 42,02 | 45,65 | 106 |
| 107 | 50,06 | 42,04 | 45,70 | 50,44 | 42,42 | 46,12 | 107 |
| 108 | 50,53 | 42,43 | 46,16 | 50,91 | 42,81 | 46,59 | 108 |
| 109 | 51,00 | 42,82 | 46,63 | 51,39 | 43,21 | 47,06 | 109 |
| 110 | 51,46 | 43,21 | 47,10 | 51,86 | 43,61 | 47,53 | 110 |

Table I

| E. V. | $C_{10}H_{18}O$ | | | $C_{10}H_{20}O$ | | | E. V. |
|-------|-----------------|---------|-------------------------|-----------------|---------|-------------------------|-------|
| | Acetate | Alcohol | Alcohol in the ong. oil | Acetate | Alcohol | Alcohol in the ong. oil | |
| 111 | 38,85 | 30,53 | 33,30 | 39,25 | 30,92 | 33,73 | 111 |
| 112 | 39,20 | 30,80 | 33,62 | 39,60 | 31,20 | 34,06 | 112 |
| 113 | 39,55 | 31,08 | 33,95 | 39,95 | 31,48 | 34,39 | 113 |
| 114 | 39,90 | 31,35 | 34,28 | 40,31 | 31,76 | 34,73 | 114 |
| 115 | 40,25 | 31,63 | 34,61 | 40,66 | 32,04 | 35,06 | 115 |
| 116 | 40,60 | 31,90 | 34,94 | 41,01 | 32,31 | 35,39 | 116 |
| 117 | 40,95 | 32,18 | 35,27 | 41,37 | 32,59 | 35,73 | 117 |
| 118 | 41,30 | 32,45 | 35,60 | 41,72 | 32,87 | 36,06 | 118 |
| 119 | 41,65 | 32,73 | 35,93 | 42,07 | 33,15 | 36,40 | 119 |
| 120 | 42,00 | 33,00 | 36,26 | 42,43 | 33,43 | 36,73 | 120 |
| 121 | 42,35 | 33,28 | 36,60 | 42,78 | 33,71 | 37,07 | 121 |
| 122 | 42,70 | 33,55 | 36,93 | 43,14 | 33,99 | 37,41 | 122 |
| 123 | 43,05 | 33,83 | 37,26 | 43,49 | 34,26 | 37,75 | 123 |
| 124 | 43,40 | 34,10 | 37,60 | 43,84 | 34,54 | 38,08 | 124 |
| 125 | 43,75 | 34,38 | 37,93 | 44,20 | 34,82 | 38,42 | 125 |
| 126 | 44,10 | 34,65 | 38,27 | 44,55 | 35,10 | 38,76 | 126 |
| 127 | 44,45 | 34,93 | 38,60 | 44,90 | 35,38 | 39,10 | 127 |
| 128 | 44,80 | 35,20 | 38,94 | 45,26 | 35,66 | 39,44 | 128 |
| 129 | 45,15 | 35,48 | 39,27 | 45,61 | 35,94 | 39,78 | 129 |
| 130 | 45,50 | 35,75 | 39,61 | 45,96 | 36,21 | 40,13 | 130 |
| 131 | 45,85 | 36,03 | 39,95 | 46,32 | 36,49 | 40,47 | 131 |
| 132 | 46,20 | 36,30 | 40,29 | 46,67 | 36,77 | 40,81 | 132 |
| 133 | 46,55 | 36,58 | 40,63 | 47,02 | 37,05 | 41,16 | 133 |
| 134 | 46,90 | 36,85 | 40,97 | 47,38 | 37,33 | 41,50 | 134 |
| 135 | 47,25 | 37,13 | 41,31 | 47,73 | 37,61 | 41,84 | 135 |
| 136 | 47,60 | 37,40 | 41,65 | 48,09 | 37,89 | 42,19 | 136 |
| 137 | 47,95 | 37,68 | 41,99 | 48,44 | 38,16 | 42,53 | 137 |
| 138 | 48,30 | 37,95 | 42,33 | 48,79 | 38,44 | 42,88 | 138 |
| 139 | 48,65 | 38,23 | 42,67 | 49,15 | 38,72 | 43,23 | 139 |
| 140 | 49,00 | 38,50 | 43,02 | 49,50 | 39,00 | 43,58 | 140 |
| 141 | 49,35 | 38,78 | 43,36 | 49,85 | 39,28 | 43,92 | 141 |
| 142 | 49,70 | 39,05 | 43,71 | 50,21 | 39,56 | 44,27 | 142 |
| 143 | 50,05 | 39,33 | 44,05 | 50,56 | 39,84 | 44,62 | 143 |
| 144 | 50,40 | 39,60 | 44,39 | 50,91 | 40,11 | 44,97 | 144 |
| 145 | 50,75 | 39,88 | 44,74 | 51,27 | 40,39 | 45,32 | 145 |
| 146 | 51,10 | 40,15 | 45,09 | 51,62 | 40,67 | 45,67 | 146 |
| 147 | 51,45 | 40,43 | 45,44 | 51,97 | 40,95 | 46,02 | 147 |
| 148 | 51,80 | 40,70 | 45,78 | 52,33 | 41,23 | 46,38 | 148 |
| 149 | 52,15 | 40,98 | 46,13 | 52,68 | 41,51 | 46,73 | 149 |
| 150 | 52,50 | 41,25 | 46,48 | 53,04 | 41,79 | 47,08 | 150 |

Table I

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| E. V. | $C_{15}H_{24}O$ | | | $C_{18}H_{26}O$ | | | E. V. |
|-------|-----------------|---------|--------------------------|-----------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 111 | 51,93 | 43,60 | 47,57 | 52,33 | 44,00 | 48,00 | 111 |
| 112 | 52,40 | 44,00 | 48,04 | 52,80 | 44,40 | 48,47 | 112 |
| 113 | 52,87 | 44,39 | 48,50 | 53,27 | 44,80 | 48,94 | 113 |
| 114 | 53,34 | 44,78 | 48,97 | 53,74 | 45,19 | 49,42 | 114 |
| 115 | 53,81 | 45,17 | 49,44 | 54,21 | 45,59 | 49,89 | 115 |
| 116 | 54,28 | 45,57 | 49,91 | 54,69 | 45,99 | 50,36 | 116 |
| 117 | 54,74 | 45,96 | 50,39 | 55,16 | 46,38 | 50,84 | 117 |
| 118 | 55,21 | 46,35 | 50,86 | 55,63 | 46,78 | 51,32 | 118 |
| 119 | 55,68 | 46,74 | 51,33 | 56,10 | 47,18 | 51,80 | 119 |
| 120 | 56,14 | 47,14 | 51,81 | 56,57 | 47,57 | 52,28 | 120 |
| 121 | 56,61 | 47,53 | 52,28 | 57,04 | 47,97 | 52,76 | 121 |
| 122 | 57,08 | 47,92 | 52,76 | 57,51 | 48,36 | 53,24 | 122 |
| 123 | 57,55 | 48,32 | 53,23 | 57,99 | 48,76 | 53,72 | 123 |
| 124 | 58,01 | 48,71 | 53,71 | 58,46 | 49,16 | 54,20 | 124 |
| 125 | 58,48 | 49,10 | 54,18 | 58,93 | 49,55 | 54,68 | 125 |
| 126 | 58,95 | 49,50 | 54,66 | 59,40 | 49,95 | 55,17 | 126 |
| 127 | 59,42 | 49,89 | 55,14 | 59,87 | 50,35 | 55,65 | 127 |
| 128 | 59,89 | 50,28 | 55,62 | 60,34 | 50,74 | 56,13 | 128 |
| 129 | 60,36 | 50,67 | 56,11 | 60,81 | 51,14 | 56,62 | 129 |
| 130 | 60,82 | 51,07 | 56,59 | 61,28 | 51,54 | 57,10 | 130 |
| 131 | 61,29 | 51,46 | 57,07 | 61,75 | 51,93 | 57,59 | 131 |
| 132 | 61,76 | 51,85 | 57,55 | 62,22 | 52,33 | 58,08 | 132 |
| 133 | 62,23 | 52,25 | 58,03 | 62,70 | 52,73 | 58,57 | 133 |
| 134 | 62,70 | 52,64 | 58,52 | 63,17 | 53,12 | 59,06 | 134 |
| 135 | 63,16 | 53,03 | 59,00 | 63,64 | 53,52 | 59,55 | 135 |
| 136 | 63,63 | 53,42 | 59,49 | 64,11 | 53,92 | 60,04 | 136 |
| 137 | 64,10 | 53,82 | 59,98 | 64,59 | 54,31 | 60,53 | 137 |
| 138 | 64,57 | 54,21 | 60,47 | 65,06 | 54,71 | 61,02 | 138 |
| 139 | 65,04 | 54,60 | 60,96 | 65,53 | 55,11 | 61,51 | 139 |
| 140 | 65,50 | 55,00 | 61,45 | 66,00 | 55,50 | 62,01 | 140 |
| 141 | 65,97 | 55,39 | 61,94 | 66,47 | 55,90 | 62,50 | 141 |
| 142 | 66,44 | 55,78 | 62,43 | 66,94 | 56,30 | 63,00 | 142 |
| 143 | 66,90 | 56,18 | 62,93 | 67,41 | 56,69 | 63,50 | 143 |
| 144 | 67,37 | 56,57 | 63,42 | 67,89 | 57,09 | 64,00 | 144 |
| 145 | 67,84 | 56,96 | 63,92 | 68,36 | 57,49 | 64,50 | 145 |
| 146 | 68,31 | 57,35 | 64,41 | 68,83 | 57,88 | 65,00 | 146 |
| 147 | 68,78 | 57,75 | 64,91 | 69,30 | 58,28 | 65,50 | 147 |
| 148 | 69,25 | 58,14 | 65,40 | 69,77 | 58,68 | 66,00 | 148 |
| 149 | 69,72 | 58,53 | 65,90 | 70,24 | 59,07 | 66,50 | 149 |
| 150 | 70,18 | 58,93 | 66,40 | 70,71 | 59,46 | 67,00 | 150 |

GILDENEISTER, THE VOLATILE OILS.

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Table I

| E. V. | C ₁₀ H ₁₈ O | | | C ₁₀ H ₂₀ O | | | E. V. |
|-------|-----------------------------------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 151 | 52,85 | 41,53 | 46,83 | 53,39 | 42,06 | 47,44 | 151 |
| 152 | 53,20 | 41,80 | 47,18 | 53,74 | 42,34 | 47,79 | 152 |
| 153 | 53,55 | 42,08 | 47,53 | 54,10 | 42,62 | 48,15 | 153 |
| 154 | 53,90 | 42,35 | 47,88 | 54,45 | 42,90 | 48,50 | 154 |
| 155 | 54,25 | 42,63 | 48,23 | 54,80 | 43,18 | 48,86 | 155 |
| 156 | 54,60 | 42,90 | 48,58 | 55,16 | 43,46 | 49,21 | 156 |
| 157 | 54,95 | 43,18 | 48,94 | 55,51 | 43,74 | 49,57 | 157 |
| 158 | 55,30 | 43,45 | 49,29 | 55,86 | 44,01 | 49,93 | 158 |
| 159 | 55,65 | 43,73 | 49,65 | 56,22 | 44,29 | 50,29 | 159 |
| 160 | 56,00 | 44,00 | 50,00 | 56,57 | 44,57 | 50,65 | 160 |
| 161 | 56,35 | 44,28 | 50,36 | 56,92 | 44,85 | 51,01 | 161 |
| 162 | 56,70 | 44,55 | 50,71 | 57,28 | 45,13 | 51,37 | 162 |
| 163 | 57,05 | 44,83 | 51,07 | 57,63 | 45,41 | 51,73 | 163 |
| 164 | 57,40 | 45,10 | 51,42 | 57,99 | 45,69 | 52,09 | 164 |
| 165 | 57,75 | 45,38 | 51,78 | 58,34 | 45,96 | 52,46 | 165 |
| 166 | 58,10 | 45,65 | 52,14 | 58,69 | 46,24 | 52,82 | 166 |
| 167 | 58,45 | 45,93 | 52,50 | 59,05 | 46,52 | 53,18 | 167 |
| 168 | 58,80 | 46,20 | 52,86 | 59,40 | 46,80 | 53,55 | 168 |
| 169 | 59,15 | 46,48 | 53,22 | 59,75 | 47,08 | 53,91 | 169 |
| 170 | 59,50 | 46,75 | 53,58 | 60,11 | 47,36 | 54,28 | 170 |
| 171 | 59,85 | 47,03 | 53,94 | 60,46 | 47,64 | 54,64 | 171 |
| 172 | 60,20 | 47,30 | 54,31 | 60,81 | 47,91 | 55,01 | 172 |
| 173 | 60,55 | 47,58 | 54,67 | 61,17 | 48,19 | 55,38 | 173 |
| 174 | 60,90 | 47,85 | 55,03 | 61,52 | 48,47 | 55,75 | 174 |
| 175 | 61,25 | 48,13 | 55,40 | 61,87 | 48,75 | 56,12 | 175 |
| 176 | 61,60 | 48,40 | 55,76 | 62,23 | 49,03 | 56,48 | 176 |
| 177 | 61,95 | 48,68 | 56,13 | 62,58 | 49,31 | 56,85 | 177 |
| 178 | 62,30 | 48,95 | 56,49 | 62,94 | 49,59 | 57,23 | 178 |
| 179 | 62,65 | 49,23 | 56,86 | 63,29 | 49,86 | 57,60 | 179 |
| 180 | 63,00 | 49,50 | 57,22 | 63,64 | 50,14 | 57,97 | 180 |
| 181 | 63,35 | 49,78 | 57,59 | 64,00 | 50,42 | 58,34 | 181 |
| 182 | 63,70 | 50,05 | 57,96 | 64,35 | 50,70 | 58,71 | 182 |
| 183 | 64,05 | 50,33 | 58,33 | 64,70 | 50,98 | 59,09 | 183 |
| 184 | 64,40 | 50,60 | 58,70 | 65,06 | 51,26 | 59,46 | 184 |
| 185 | 64,75 | 50,88 | 59,07 | 65,41 | 51,54 | 59,84 | 185 |
| 186 | 65,10 | 51,15 | 59,44 | 65,76 | 51,81 | 60,21 | 186 |
| 187 | 65,45 | 51,43 | 59,81 | 66,12 | 52,09 | 60,59 | 187 |
| 188 | 65,80 | 51,70 | 60,19 | 66,47 | 52,37 | 60,97 | 188 |
| 189 | 66,15 | 51,98 | 60,56 | 66,82 | 52,65 | 61,35 | 189 |
| 190 | 66,50 | 52,25 | 60,93 | 67,18 | 52,93 | 61,72 | 190 |

Table I

| E. V. | C ₁₈ H ₂₄ O | | | C ₁₈ H ₂₄ O | | | E. V. |
|-------|-----------------------------------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 151 | 70,65 | 59,32 | 66,90 | 71,19 | 59,86 | 67,51 | 151 |
| 152 | 71,12 | 59,71 | 67,40 | 71,66 | 60,26 | 68,01 | 152 |
| 153 | 71,58 | 60,10 | 67,90 | 72,13 | 60,65 | 68,52 | 153 |
| 154 | 72,05 | 60,50 | 68,40 | 72,60 | 61,05 | 69,02 | 154 |
| 155 | 72,52 | 60,89 | 68,90 | 73,07 | 61,45 | 69,53 | 155 |
| 156 | 72,99 | 61,28 | 69,41 | 73,54 | 61,84 | 70,04 | 156 |
| 157 | 73,46 | 61,68 | 69,91 | 74,01 | 62,24 | 70,55 | 157 |
| 158 | 73,92 | 62,07 | 70,42 | 74,49 | 62,64 | 71,06 | 158 |
| 159 | 74,39 | 62,46 | 70,92 | 74,96 | 63,03 | 71,57 | 159 |
| 160 | 74,86 | 62,86 | 71,43 | 75,43 | 63,43 | 72,08 | 160 |
| 161 | 75,33 | 63,25 | 71,93 | 75,90 | 63,83 | 72,59 | 161 |
| 162 | 75,80 | 63,64 | 72,44 | 76,37 | 64,22 | 73,10 | 162 |
| 163 | 76,26 | 64,03 | 72,95 | 76,84 | 64,62 | 73,62 | 163 |
| 164 | 76,73 | 64,42 | 73,46 | 77,31 | 65,02 | 74,13 | 164 |
| 165 | 77,20 | 64,82 | 73,97 | 77,78 | 65,41 | 74,65 | 165 |
| 166 | 77,67 | 65,21 | 74,49 | 78,26 | 65,81 | 75,16 | 166 |
| 167 | 78,14 | 65,60 | 75,00 | 78,73 | 66,21 | 75,68 | 167 |
| 168 | 78,60 | 66,00 | 75,52 | 79,20 | 66,60 | 76,20 | 168 |
| 169 | 79,07 | 66,39 | 76,03 | 79,67 | 67,00 | 76,72 | 169 |
| 170 | 79,54 | 66,79 | 76,55 | 80,14 | 67,39 | 77,24 | 170 |
| 171 | 80,01 | 67,18 | 77,06 | 80,61 | 67,79 | 77,76 | 171 |
| 172 | 80,48 | 67,57 | 77,58 | 81,08 | 68,19 | 78,28 | 172 |
| 173 | 80,94 | 67,96 | 78,10 | 81,56 | 68,58 | 78,81 | 173 |
| 174 | 81,41 | 68,35 | 78,62 | 82,03 | 68,98 | 79,33 | 174 |
| 175 | 81,88 | 68,75 | 79,14 | 82,50 | 69,38 | 79,85 | 175 |
| 176 | 82,35 | 69,14 | 79,66 | 82,97 | 69,77 | 80,38 | 176 |
| 177 | 82,81 | 69,54 | 80,18 | 83,44 | 70,17 | 80,91 | 177 |
| 178 | 83,28 | 69,93 | 80,70 | 83,91 | 70,57 | 81,43 | 178 |
| 179 | 83,75 | 70,32 | 81,23 | 84,38 | 70,96 | 81,96 | 179 |
| 180 | 84,21 | 70,71 | 81,75 | 84,86 | 71,36 | 82,49 | 180 |
| 181 | 84,68 | 71,10 | 82,28 | 85,33 | 71,76 | 83,02 | 181 |
| 182 | 85,15 | 71,50 | 82,80 | 85,80 | 72,15 | 83,55 | 182 |
| 183 | 85,62 | 71,89 | 83,33 | 86,27 | 72,55 | 84,09 | 183 |
| 184 | 86,09 | 72,28 | 83,86 | 86,74 | 72,95 | 84,62 | 184 |
| 185 | 86,56 | 72,68 | 84,39 | 87,21 | 73,34 | 85,15 | 185 |
| 186 | 87,03 | 73,07 | 84,92 | 87,68 | 73,74 | 85,69 | 186 |
| 187 | 87,49 | 73,46 | 85,45 | 88,16 | 74,14 | 86,22 | 187 |
| 188 | 87,96 | 73,86 | 85,98 | 88,63 | 74,53 | 86,76 | 188 |
| 189 | 88,43 | 74,25 | 86,51 | 89,10 | 74,93 | 87,30 | 189 |
| 190 | 88,89 | 74,64 | 87,05 | 89,57 | 75,32 | 87,84 | 190 |

Table I

| E. V. | C ₁₀ H ₁₈ O | | | C ₁₀ H ₁₈ O | | | E. V. |
|-------|-----------------------------------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 191 | 66,85 | 52,53 | 61,31 | 67,53 | 53,21 | 62,10 | 191 |
| 192 | 67,20 | 52,80 | 61,68 | 67,89 | 53,49 | 62,48 | 192 |
| 193 | 67,55 | 53,08 | 62,06 | 68,24 | 53,76 | 62,86 | 193 |
| 194 | 67,90 | 53,35 | 62,43 | 68,59 | 54,04 | 63,24 | 194 |
| 195 | 68,25 | 53,63 | 62,81 | 68,95 | 54,32 | 63,63 | 195 |
| 196 | 68,60 | 53,90 | 63,19 | 69,30 | 54,60 | 64,01 | 196 |
| 197 | 68,95 | 54,18 | 63,57 | 69,65 | 54,88 | 64,39 | 197 |
| 198 | 69,30 | 54,45 | 63,95 | 70,01 | 55,16 | 64,78 | 198 |
| 199 | 69,65 | 54,73 | 64,33 | 70,36 | 55,44 | 65,16 | 199 |
| 200 | 70,00 | 55,00 | 64,71 | 70,71 | 55,71 | 65,55 | 200 |
| 201 | 70,35 | 55,28 | 65,09 | 71,07 | 55,99 | 65,93 | 201 |
| 202 | 70,70 | 55,55 | 65,47 | 71,42 | 56,27 | 66,32 | 202 |
| 203 | 71,05 | 55,83 | 65,85 | 71,77 | 56,55 | 66,71 | 203 |
| 204 | 71,40 | 56,10 | 66,23 | 72,13 | 56,83 | 67,09 | 204 |
| 205 | 71,75 | 56,38 | 66,62 | 72,48 | 57,11 | 67,48 | 205 |
| 206 | 72,10 | 56,65 | 67,00 | 72,84 | 57,39 | 67,87 | 206 |
| 207 | 72,45 | 56,93 | 67,39 | 73,19 | 57,66 | 68,26 | 207 |
| 208 | 72,80 | 57,20 | 67,77 | 73,54 | 57,94 | 68,65 | 208 |
| 209 | 73,15 | 57,48 | 68,16 | 73,90 | 58,22 | 69,04 | 209 |
| 210 | 73,50 | 57,75 | 68,55 | 74,25 | 58,50 | 69,44 | 210 |
| 211 | 73,85 | 58,03 | 68,93 | 74,60 | 58,78 | 69,83 | 211 |
| 212 | 74,20 | 58,30 | 69,32 | 74,96 | 59,06 | 70,22 | 212 |
| 213 | 74,55 | 58,58 | 69,71 | 75,31 | 59,34 | 70,62 | 213 |
| 214 | 74,90 | 58,85 | 70,10 | 75,66 | 59,61 | 71,01 | 214 |
| 215 | 75,25 | 59,13 | 70,49 | 76,02 | 59,89 | 71,41 | 215 |
| 216 | 75,60 | 59,40 | 70,88 | 76,37 | 60,17 | 71,80 | 216 |
| 217 | 75,95 | 59,68 | 71,28 | 76,72 | 60,45 | 72,20 | 217 |
| 218 | 76,30 | 59,95 | 71,67 | 77,08 | 60,73 | 72,60 | 218 |
| 219 | 76,65 | 60,23 | 72,06 | 77,43 | 61,01 | 73,00 | 219 |
| 220 | 77,00 | 60,50 | 72,45 | 77,79 | 61,29 | 73,40 | 220 |
| 221 | 77,35 | 60,78 | 72,85 | 78,14 | 61,56 | 73,80 | 221 |
| 222 | 77,70 | 61,05 | 73,25 | 78,49 | 61,84 | 74,20 | 222 |
| 223 | 78,05 | 61,33 | 73,64 | 78,85 | 62,12 | 74,60 | 223 |
| 224 | 78,40 | 61,60 | 74,04 | 79,20 | 62,40 | 75,00 | 224 |
| 225 | 78,75 | 61,88 | 74,44 | 79,55 | 62,68 | 75,40 | 225 |
| 226 | 79,10 | 62,15 | 74,84 | 79,91 | 62,96 | 75,81 | 226 |
| 227 | 79,45 | 62,43 | 75,23 | 80,26 | 63,24 | 76,21 | 227 |
| 228 | 79,80 | 62,70 | 75,63 | 80,61 | 63,51 | 76,62 | 228 |
| 229 | 80,15 | 62,98 | 76,03 | 80,97 | 63,79 | 77,02 | 229 |
| 230 | 80,50 | 63,25 | 76,44 | 81,32 | 64,07 | 77,43 | 230 |

Table I

| C ₁₈ H ₃₄ O | | | | C ₁₈ H ₃₆ O | | | |
|-----------------------------------|---------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| E. V. | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | E. V. |
| 191 | 89,36 | 75,03 | 87,58 | 90,04 | 75,72 | 88,38 | 191 |
| 192 | 89,83 | 75,42 | 88,12 | 90,51 | 76,12 | 88,92 | 192 |
| 193 | 90,30 | 75,82 | 88,65 | 90,98 | 76,51 | 89,46 | 193 |
| 194 | 90,77 | 76,21 | 89,19 | 91,46 | 76,91 | 90,00 | 194 |
| 195 | 91,24 | 76,60 | 89,73 | 91,93 | 77,31 | 90,54 | 195 |
| 196 | 91,70 | 77,00 | 90,27 | 92,40 | 77,70 | 91,09 | 196 |
| 197 | 92,17 | 77,39 | 90,81 | 92,87 | 78,10 | 91,64 | 197 |
| 198 | 92,64 | 77,78 | 91,35 | 93,34 | 78,50 | 92,18 | 198 |
| 199 | 93,11 | 78,17 | 91,89 | 93,81 | 78,89 | 92,73 | 199 |
| 200 | 93,57 | 78,57 | 92,44 | 94,28 | 79,29 | 93,28 | 200 |
| | | | | | | | |
| 201 | 94,04 | 78,96 | 92,98 | 94,76 | 79,68 | 93,83 | 201 |
| 202 | 94,51 | 79,35 | 93,53 | 95,23 | 80,08 | 94,38 | 202 |
| 203 | 94,98 | 79,75 | 94,07 | 95,70 | 80,48 | 94,93 | 203 |
| 204 | 95,44 | 80,14 | 94,62 | 96,17 | 80,87 | 95,48 | 204 |
| 205 | 95,91 | 80,53 | 95,17 | 96,64 | 81,26 | 96,03 | 205 |
| 206 | 96,38 | 80,92 | 95,72 | 97,11 | 81,66 | 96,59 | 206 |
| 207 | 96,85 | 81,32 | 96,27 | 97,58 | 82,06 | 97,14 | 207 |
| 208 | 97,32 | 81,71 | 96,82 | 98,05 | 82,45 | 97,70 | 208 |
| 209 | 97,79 | 82,10 | 97,37 | 98,52 | 82,85 | 98,25 | 209 |
| 210 | 98,25 | 82,50 | 97,92 | 99,00 | 83,25 | 98,81 | 210 |
| | | | | | | | |
| 211 | 98,72 | 82,89 | 98,48 | 99,47 | 83,64 | 99,37 | 211 |
| 212 | 99,19 | 83,28 | 99,03 | 99,94 | 84,04 | 99,93 | 212 |
| 213 | 99,66 | 83,67 | 99,59 | 100,41 | 84,44 | 100,49 | 213 |
| 214 | 100,12 | 84,07 | 100,14 | | | | 214 |

Table I

| E. V. | C ₁₀ H ₁₈ O | | | C ₁₀ H ₁₈ O | | | E. V. |
|-------|-----------------------------------|---------|--------------------------|-----------------------------------|---------|--------------------------|-------|
| | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | |
| 231 | 80,85 | 63,53 | 76,84 | 81,67 | 64,35 | 77,83 | 231 |
| 232 | 81,20 | 63,80 | 77,24 | 82,03 | 64,63 | 78,24 | 232 |
| 233 | 81,55 | 64,08 | 77,64 | 82,38 | 64,91 | 78,65 | 233 |
| 234 | 81,90 | 64,35 | 78,05 | 82,74 | 65,19 | 79,06 | 234 |
| 235 | 82,25 | 64,63 | 78,45 | 83,09 | 65,46 | 79,47 | 235 |
| 236 | 82,60 | 64,90 | 78,86 | 83,44 | 65,74 | 79,88 | 236 |
| 237 | 82,95 | 65,18 | 79,27 | 83,80 | 66,02 | 80,29 | 237 |
| 238 | 83,30 | 65,45 | 79,67 | 84,15 | 66,30 | 80,71 | 238 |
| 239 | 83,65 | 65,73 | 80,08 | 84,50 | 66,58 | 81,12 | 239 |
| 240 | 84,00 | 66,00 | 80,49 | 84,86 | 66,86 | 81,53 | 240 |
| 241 | 84,35 | 66,28 | 80,90 | 85,21 | 67,14 | 81,95 | 241 |
| 242 | 84,70 | 66,55 | 81,31 | 85,56 | 67,41 | 82,36 | 242 |
| 243 | 85,05 | 66,83 | 81,72 | 85,92 | 67,69 | 82,78 | 243 |
| 244 | 85,40 | 67,10 | 82,13 | 86,27 | 67,97 | 83,20 | 244 |
| 245 | 85,75 | 67,38 | 82,54 | 86,62 | 68,25 | 83,61 | 245 |
| 246 | 86,10 | 67,65 | 82,96 | 86,98 | 68,53 | 84,03 | 246 |
| 247 | 86,45 | 67,93 | 83,37 | 87,33 | 68,81 | 84,45 | 247 |
| 248 | 86,80 | 68,20 | 83,78 | 87,69 | 69,09 | 84,87 | 248 |
| 249 | 87,15 | 68,48 | 84,20 | 88,04 | 69,36 | 85,29 | 249 |
| 250 | 87,50 | 68,75 | 84,62 | 88,39 | 69,64 | 85,71 | 250 |
| 251 | 87,85 | 69,03 | 85,03 | 88,75 | 69,92 | 86,14 | 251 |
| 252 | 88,20 | 69,30 | 85,45 | 89,10 | 70,20 | 86,56 | 252 |
| 253 | 88,55 | 69,58 | 85,87 | 89,45 | 70,48 | 86,98 | 253 |
| 254 | 88,90 | 69,85 | 86,29 | 89,81 | 70,76 | 87,41 | 254 |
| 255 | 89,25 | 70,13 | 86,71 | 90,16 | 71,04 | 87,83 | 255 |
| 256 | 89,60 | 70,40 | 87,13 | 90,51 | 71,31 | 88,26 | 256 |
| 257 | 89,95 | 70,68 | 87,55 | 90,87 | 71,59 | 88,69 | 257 |
| 258 | 90,30 | 70,95 | 87,97 | 91,22 | 71,87 | 89,11 | 258 |
| 259 | 90,65 | 71,23 | 88,40 | 91,57 | 72,15 | 89,54 | 259 |
| 260 | 91,00 | 71,50 | 88,82 | 91,93 | 72,43 | 89,97 | 260 |
| 261 | 91,35 | 71,78 | 89,25 | 92,28 | 72,71 | 90,40 | 261 |
| 262 | 91,70 | 72,05 | 89,67 | 92,64 | 72,99 | 90,83 | 262 |
| 263 | 92,05 | 72,33 | 90,10 | 92,99 | 73,26 | 91,27 | 263 |
| 264 | 92,40 | 72,60 | 90,52 | 93,34 | 73,54 | 91,70 | 264 |
| 265 | 92,75 | 72,88 | 90,95 | 93,70 | 73,82 | 92,13 | 265 |
| 266 | 93,10 | 73,15 | 91,38 | 94,05 | 74,10 | 92,57 | 266 |
| 267 | 93,45 | 73,43 | 91,81 | 94,40 | 74,38 | 93,00 | 267 |
| 268 | 93,80 | 73,70 | 92,24 | 94,76 | 74,66 | 93,44 | 268 |
| 269 | 94,15 | 73,98 | 92,67 | 95,11 | 74,94 | 93,87 | 269 |
| 270 | 94,50 | 74,25 | 93,10 | 95,46 | 75,21 | 94,31 | 270 |

Table I

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| C ₁₀ H ₁₈ O | | | | C ₁₀ H ₂₀ O | | | |
|-----------------------------------|---------|---------|----------------------------|-----------------------------------|---------|----------------------------|-------|
| E. V. | Acetate | Alcohol | Alcohol in the org. oil | Acetate | Alcohol | Alcohol in the org. oil | E. V. |
| 271 | 94,85 | 74,53 | 93,54 | 95,82 | 75,49 | 94,75 | 271 |
| 272 | 95,20 | 74,80 | 93,97 | 96,17 | 75,77 | 95,19 | 272 |
| 273 | 95,55 | 75,08 | 94,40 | 96,52 | 76,05 | 95,63 | 273 |
| 274 | 95,90 | 75,35 | 94,84 | 96,88 | 76,33 | 96,07 | 274 |
| 275 | 96,25 | 75,63 | 95,28 | 97,23 | 76,61 | 96,51 | 275 |
| 276 | 96,60 | 75,90 | 95,71 | 97,59 | 76,89 | 96,96 | 276 |
| 277 | 96,95 | 76,18 | 96,15 | 97,94 | 77,16 | 97,40 | 277 |
| 278 | 97,30 | 76,45 | 96,59 | 98,29 | 77,44 | 97,84 | 278 |
| 279 | 97,65 | 76,73 | 97,03 | 98,65 | 77,72 | 98,29 | 279 |
| 280 | 98,00 | 77,00 | 97,47 | 99,00 | 78,00 | 98,73 | 280 |
| 281 | 98,35 | 77,28 | 97,91 | 99,35 | 78,28 | 99,18 | 281 |
| 282 | 98,70 | 77,55 | 98,35 | 99,71 | 78,56 | 99,63 | 282 |
| 283 | 99,05 | 77,83 | 98,80 | 100,06 | 78,84 | 100,08 | 283 |
| 284 | 99,40 | 78,10 | 99,24 | | | | — |
| 285 | 99,75 | 78,38 | 99,68 | | | | — |
| 286 | 100,10 | 78,65 | 100,13 | | | | — |

Tiglate of geraniol: C₂H₄COOC₁₀H₁₇

| E. V. | Ester | L. V. | Ester | E. V. | Ester | L. V. | Ester | E. V. | Ester |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 | 0,42 | 21 | 8,85 | 41 | 17,28 | 61 | 25,71 | 81 | 34,13 |
| 2 | 0,84 | 22 | 9,27 | 42 | 17,70 | 62 | 26,13 | 82 | 34,55 |
| 3 | 1,26 | 23 | 9,69 | 43 | 18,12 | 63 | 26,55 | 83 | 34,98 |
| 4 | 1,69 | 24 | 10,11 | 44 | 18,54 | 64 | 26,97 | 84 | 35,40 |
| 5 | 2,11 | 25 | 10,54 | 45 | 18,96 | 65 | 27,39 | 85 | 35,82 |
| 6 | 2,53 | 26 | 10,96 | 46 | 19,38 | 66 | 27,81 | 86 | 36,24 |
| 7 | 2,95 | 27 | 11,38 | 47 | 19,80 | 67 | 28,23 | 87 | 36,66 |
| 8 | 3,37 | 28 | 11,80 | 48 | 20,23 | 68 | 28,65 | 88 | 37,09 |
| 9 | 3,79 | 29 | 12,22 | 49 | 20,65 | 69 | 29,08 | 89 | 37,51 |
| 10 | 4,21 | 30 | 12,64 | 50 | 21,07 | 70 | 29,50 | 90 | 37,93 |
| 11 | 4,63 | 31 | 13,06 | 51 | 21,49 | 71 | 29,92 | 91 | 38,35 |
| 12 | 5,05 | 32 | 13,49 | 52 | 21,91 | 72 | 30,34 | 92 | 38,77 |
| 13 | 5,47 | 33 | 13,91 | 53 | 22,33 | 73 | 30,76 | 93 | 39,19 |
| 14 | 5,90 | 34 | 14,33 | 54 | 22,75 | 74 | 31,18 | 94 | 39,62 |
| 15 | 6,32 | 35 | 14,75 | 55 | 23,18 | 75 | 31,61 | 95 | 40,04 |
| 16 | 6,74 | 36 | 15,17 | 56 | 23,60 | 76 | 32,03 | 96 | 40,46 |
| 17 | 7,16 | 37 | 15,59 | 57 | 24,02 | 77 | 32,45 | 97 | 40,88 |
| 18 | 7,58 | 38 | 16,01 | 58 | 24,44 | 78 | 32,87 | 98 | 41,30 |
| 19 | 8,01 | 39 | 16,44 | 59 | 24,87 | 79 | 33,29 | 99 | 41,72 |
| 20 | 8,43 | 40 | 16,86 | 60 | 25,29 | 80 | 33,71 | 100 | 42,14 |

for Determining the Ester Value (Acid Value, Saponification Value)
cc. $\frac{n}{2}$ Potassium Hy

| cc. $\frac{n}{2}$ KOH | E. V. (A. V.; S. V.) | C ₁₀ H ₁₈ O | | | | C ₁₀ H ₂₀ O | |
|--------------------------|----------------------------|-----------------------------------|---------|---------|--------------------------------|-----------------------------------|---------|
| | | Eglate | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol |
| 0,1 | | 0,79 | 0,65 | 0,51 | 0,51 | 0,66 | 0,52 |
| 0,2 | | 1,57 | 1,30 | 1,02 | 1,02 | 1,32 | 1,04 |
| 0,3 | | 2,36 | 1,96 | 1,54 | 1,54 | 1,98 | 1,56 |
| 0,4 | | 3,15 | 2,61 | 2,05 | 2,06 | 2,64 | 2,08 |
| 0,5 | | 3,93 | 3,26 | 2,56 | 2,58 | 3,30 | 2,60 |
| 0,6 | | 4,72 | 3,92 | 3,08 | 3,10 | 3,96 | 3,12 |
| 0,7 | | 5,50 | 4,57 | 3,59 | 3,63 | 4,62 | 3,64 |
| 0,8 | | 6,29 | 5,22 | 4,10 | 4,15 | 5,28 | 4,16 |
| 0,9 | | 7,08 | 5,88 | 4,62 | 4,68 | 5,94 | 4,68 |
| 1,0 | | 7,86 | 6,53 | 5,13 | 5,21 | 6,60 | 5,20 |
| 1,1 | | 8,65 | 7,18 | 5,64 | 5,73 | 7,26 | 5,72 |
| 1,2 | | 9,44 | 7,84 | 6,16 | 6,25 | 7,92 | 6,24 |
| 1,3 | | 10,23 | 8,49 | 6,67 | 6,79 | 8,58 | 6,76 |
| 1,4 | | 11,01 | 9,14 | 7,18 | 7,32 | 9,24 | 7,28 |
| 1,5 | | 11,80 | 9,80 | 7,70 | 7,86 | 9,90 | 7,80 |
| 1,6 | | 12,59 | 10,45 | 8,21 | 8,40 | 10,56 | 8,32 |
| 1,7 | | 13,37 | 11,10 | 8,72 | 8,94 | 11,22 | 8,84 |
| 1,8 | | 14,16 | 11,76 | 9,24 | 9,48 | 11,88 | 9,36 |
| 1,9 | | 14,95 | 12,41 | 9,75 | 10,02 | 12,54 | 9,88 |
| 2,0 | | 15,73 | 13,06 | 10,26 | 10,56 | 13,20 | 10,40 |
| 2,1 | | 16,52 | 13,72 | 10,78 | 11,11 | 13,86 | 10,92 |
| 2,2 | | 17,31 | 14,37 | 11,29 | 11,65 | 14,52 | 11,44 |
| 2,3 | | 18,09 | 15,02 | 11,80 | 12,20 | 15,18 | 11,96 |
| 2,4 | | 18,88 | 15,68 | 12,32 | 12,75 | 15,84 | 12,48 |
| 2,5 | | 19,67 | 16,33 | 12,83 | 13,30 | 16,50 | 13,00 |
| 2,6 | | 20,45 | 16,98 | 13,34 | 13,85 | 17,16 | 13,52 |
| 2,7 | | 21,24 | 17,64 | 13,86 | 14,41 | 17,82 | 14,04 |
| 2,8 | | 22,03 | 18,29 | 14,37 | 14,96 | 18,48 | 14,56 |
| 2,9 | | 22,81 | 18,94 | 14,88 | 15,51 | 19,14 | 15,08 |
| 3,0 | | 23,60 | 19,60 | 15,40 | 16,07 | 19,80 | 15,60 |

II

Percentage Content of Alcohol and Ester directly from the Number of 1.50 g. of Oil are used.

| | C ₁₈ H ₃₄ O | | Acetate | C ₁₈ H ₃₂ O | | E. V. (A. V.; S. V.) | cc. n 2 KOH |
|---|-----------------------------------|--------------------------------|---------|-----------------------------------|--------------------------------|----------------------------|----------------------|
| | Alcohol | Alcohol in the orig. oil | | Alcohol | Alcohol in the orig. oil | | |
| 7 | 0,73 | 0,73 | 0,88 | 0,74 | 0,74 | | 0,1 |
| 4 | 1,46 | 1,47 | 1,76 | 1,48 | 1,48 | | 0,2 |
| 2 | 2,20 | 2,21 | 2,64 | 2,22 | 2,22 | | 0,3 |
| 9 | 2,93 | 2,95 | 3,52 | 2,96 | 2,97 | | 0,4 |
| 6 | 3,66 | 3,69 | 4,40 | 3,70 | 3,72 | | 0,5 |
| 4 | 4,40 | 4,44 | 5,28 | 4,44 | 4,48 | | 0,6 |
| 1 | 5,13 | 5,19 | 6,16 | 5,18 | 5,23 | | 0,7 |
| 8 | 5,86 | 5,94 | 7,04 | 5,92 | 5,98 | | 0,8 |
| 6 | 6,60 | 6,69 | 7,92 | 6,66 | 6,74 | | 0,9 |
| 3 | 7,33 | 7,44 | 8,80 | 7,40 | 7,50 | | 1,0 |
| 0 | 8,06 | 8,19 | 9,68 | 8,14 | 8,26 | | 1,1 |
| 8 | 8,80 | 8,95 | 10,56 | 8,88 | 9,03 | | 1,2 |
| 5 | 9,53 | 9,71 | 11,44 | 9,62 | 9,80 | | 1,3 |
| 2 | 10,26 | 10,47 | 12,32 | 10,36 | 10,57 | | 1,4 |
| 0 | 11,00 | 11,24 | 13,20 | 11,10 | 11,34 | | 1,5 |
| 7 | 11,73 | 12,00 | 14,08 | 11,84 | 12,11 | | 1,6 |
| 4 | 12,46 | 12,77 | 14,96 | 12,58 | 12,88 | | 1,7 |
| 2 | 13,20 | 13,54 | 15,84 | 13,32 | 13,66 | | 1,8 |
| 9 | 13,93 | 14,32 | 16,72 | 14,06 | 14,45 | | 1,9 |
| 6 | 14,66 | 15,09 | 17,60 | 14,80 | 15,23 | | 2,0 |
| 4 | 15,40 | 15,87 | 18,48 | 15,54 | 16,01 | | 2,1 |
| 1 | 16,13 | 16,65 | 19,36 | 16,28 | 16,80 | | 2,2 |
| 8 | 16,86 | 17,43 | 20,24 | 17,02 | 17,58 | | 2,3 |
| 6 | 17,60 | 18,21 | 21,12 | 17,76 | 18,37 | | 2,4 |
| 3 | 18,33 | 19,00 | 22,00 | 18,50 | 19,17 | | 2,5 |
| 0 | 19,06 | 19,79 | 22,88 | 19,24 | 19,97 | | 2,6 |
| 8 | 19,80 | 20,58 | 23,76 | 19,98 | 20,76 | | 2,7 |
| 5 | 20,53 | 21,37 | 24,64 | 20,72 | 21,56 | | 2,8 |
| 2 | 21,26 | 22,16 | 25,52 | 21,46 | 22,36 | | 2,9 |
| 0 | 22,00 | 22,96 | 26,40 | 22,20 | 23,17 | | 3,0 |

Table II

| cc. n 2 KOH | E. V. (A. V., S. V.) | C ₁₀ H ₁₈ O | | | | C ₁₀ H ₁₆ O | |
|-------------------|----------------------------|-----------------------------------|---------|---------|--------------------------------|-----------------------------------|---------|
| | | Tiglate | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol |
| 3,1 | | 24,39 | 20,25 | 15,91 | 16,63 | 20,46 | 16,12 |
| 3,2 | | 25,17 | 20,90 | 16,42 | 17,20 | 21,12 | 16,64 |
| 3,3 | | 25,96 | 21,56 | 16,94 | 17,76 | 21,78 | 17,16 |
| 3,4 | | 26,75 | 22,21 | 17,45 | 18,33 | 22,44 | 17,68 |
| 3,5 | | 27,53 | 22,86 | 17,96 | 18,90 | 23,10 | 18,20 |
| 3,6 | | 28,32 | 23,52 | 18,48 | 19,46 | 23,76 | 18,72 |
| 3,7 | | 29,11 | 24,17 | 18,99 | 20,03 | 24,42 | 19,24 |
| 3,8 | | 29,89 | 24,82 | 19,50 | 20,60 | 25,08 | 19,76 |
| 3,9 | | 30,68 | 25,48 | 20,02 | 21,18 | 25,74 | 20,28 |
| 4,0 | | 31,47 | 26,13 | 20,53 | 21,75 | 26,40 | 20,80 |
| 4,1 | | 32,25 | 26,78 | 21,04 | 22,32 | 27,06 | 21,32 |
| 4,2 | | 33,04 | 27,44 | 21,56 | 22,90 | 27,72 | 21,84 |
| 4,3 | | 33,83 | 28,09 | 22,07 | 23,48 | 28,38 | 22,36 |
| 4,4 | | 34,61 | 28,74 | 22,58 | 24,06 | 29,04 | 22,88 |
| 4,5 | | 35,40 | 29,40 | 23,10 | 24,65 | 29,70 | 23,40 |
| 4,6 | | 36,19 | 30,05 | 23,61 | 25,24 | 30,36 | 23,92 |
| 4,7 | | 36,97 | 30,70 | 24,12 | 25,82 | 31,02 | 24,44 |
| 4,8 | | 37,76 | 31,36 | 24,64 | 26,41 | 31,68 | 24,96 |
| 4,9 | | 38,55 | 32,01 | 25,15 | 27,01 | 32,34 | 25,48 |
| 5,0 | | 39,33 | 32,66 | 25,66 | 27,60 | 33,00 | 26,00 |
| 5,1 | | 40,12 | 33,32 | 26,18 | 28,19 | 33,66 | 26,52 |
| 5,2 | | 40,91 | 33,97 | 26,69 | 28,79 | 34,32 | 27,04 |
| 5,3 | | 41,69 | 34,62 | 27,20 | 29,39 | 34,98 | 27,56 |
| 5,4 | | 42,48 | 35,28 | 27,72 | 29,99 | 35,64 | 28,08 |
| 5,5 | | 43,27 | 35,93 | 28,23 | 30,59 | 36,30 | 28,60 |
| 5,6 | | 44,05 | 36,58 | 28,74 | 31,19 | 36,96 | 29,12 |
| 5,7 | | 44,84 | 37,24 | 29,26 | 31,80 | 37,62 | 29,64 |
| 5,8 | | 45,63 | 37,89 | 29,77 | 32,40 | 38,28 | 30,16 |
| 5,9 | | 46,41 | 38,54 | 30,28 | 33,01 | 38,94 | 30,68 |
| 6,0 | | 47,20 | 39,20 | 30,80 | 33,62 | 39,60 | 31,20 |
| 6,1 | | 47,99 | 39,85 | 31,31 | 34,24 | 40,26 | 31,72 |
| 6,2 | | 48,77 | 40,50 | 31,82 | 34,85 | 40,92 | 32,24 |
| 6,3 | | 49,56 | 41,16 | 32,34 | 35,47 | 41,58 | 32,76 |
| 6,4 | | 50,35 | 41,81 | 32,85 | 36,09 | 42,24 | 33,28 |
| 6,5 | | 51,13 | 42,46 | 33,36 | 36,71 | 42,90 | 33,80 |
| 6,6 | | 51,92 | 43,12 | 33,88 | 37,33 | 43,56 | 34,32 |
| 6,7 | | 52,71 | 43,77 | 34,39 | 37,96 | 44,22 | 34,84 |
| 6,8 | | 53,49 | 44,42 | 34,90 | 38,58 | 44,88 | 35,36 |
| 6,9 | | 54,28 | 45,08 | 35,42 | 39,20 | 45,54 | 35,88 |
| 7,0 | | 55,07 | 45,73 | 35,93 | 39,83 | 46,20 | 36,40 |

Table II

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| C ₁₅ H ₃₄ O | | | C ₁₅ H ₃₂ O | | | E. V. (A. V.; S. V.) | cc. n 2 KOH |
|-----------------------------------|--------------------------------|---------|-----------------------------------|--------------------------------|------|----------------------------|----------------------|
| Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | | | |
| 22,73 | 23,76 | 27,28 | 22,94 | 23,98 | 17,8 | 3,1 | |
| 23,46 | 24,56 | 28,16 | 23,68 | 24,79 | 18,1 | 3,2 | |
| 24,20 | 25,37 | 29,04 | 24,42 | 25,60 | 18,3 | 3,3 | |
| 24,93 | 26,17 | 29,92 | 25,16 | 26,41 | 18,5 | 3,4 | |
| 25,66 | 26,98 | 30,80 | 25,90 | 27,23 | 18,7 | 3,5 | |
| 26,40 | 27,79 | 31,68 | 26,64 | 28,05 | 18,9 | 3,6 | |
| 27,13 | 28,61 | 32,56 | 27,38 | 28,88 | 19,1 | 3,7 | |
| 27,86 | 29,43 | 33,44 | 28,12 | 29,70 | 19,3 | 3,8 | |
| 28,60 | 30,25 | 34,32 | 28,86 | 30,52 | 19,5 | 3,9 | |
| 29,33 | 31,07 | 35,20 | 29,60 | 31,35 | 19,7 | 4,0 | |
| 30,06 | 31,89 | 36,08 | 30,34 | 32,18 | 19,9 | 4,1 | |
| 30,80 | 32,72 | 36,96 | 31,08 | 33,02 | 20,1 | 4,2 | |
| 31,53 | 33,55 | 37,84 | 31,82 | 33,86 | 20,3 | 4,3 | |
| 32,26 | 34,38 | 38,72 | 32,56 | 34,70 | 20,5 | 4,4 | |
| 33,00 | 35,22 | 39,60 | 33,30 | 35,54 | 20,7 | 4,5 | |
| 33,73 | 36,05 | 40,48 | 34,04 | 36,38 | 20,9 | 4,6 | |
| 34,46 | 36,89 | 41,36 | 34,78 | 37,23 | 21,1 | 4,7 | |
| 35,20 | 37,73 | 42,24 | 35,52 | 38,07 | 21,3 | 4,8 | |
| 35,93 | 38,58 | 43,12 | 36,26 | 38,92 | 21,5 | 4,9 | |
| 36,66 | 39,42 | 44,00 | 37,00 | 39,78 | 21,7 | 5,0 | |
| 37,40 | 40,27 | 44,88 | 37,74 | 40,64 | 21,9 | 5,1 | |
| 38,13 | 41,13 | 45,76 | 38,48 | 41,50 | 22,1 | 5,2 | |
| 38,86 | 41,98 | 46,64 | 39,22 | 42,36 | 22,3 | 5,3 | |
| 39,60 | 42,84 | 47,52 | 39,96 | 43,23 | 22,5 | 5,4 | |
| 40,33 | 43,70 | 48,40 | 40,70 | 44,09 | 22,7 | 5,5 | |
| 41,06 | 44,56 | 49,28 | 41,44 | 44,96 | 22,9 | 5,6 | |
| 41,80 | 45,42 | 50,16 | 42,18 | 45,83 | 23,1 | 5,7 | |
| 42,53 | 46,29 | 51,04 | 42,92 | 46,71 | 23,3 | 5,8 | |
| 43,26 | 47,16 | 51,92 | 43,66 | 47,59 | 23,5 | 5,9 | |
| 44,00 | 48,04 | 52,80 | 44,40 | 48,47 | 23,7 | 6,0 | |
| 44,73 | 48,91 | 53,68 | 45,14 | 49,35 | 23,9 | 6,1 | |
| 45,46 | 49,79 | 54,56 | 45,88 | 50,24 | 24,1 | 6,2 | |
| 46,20 | 50,67 | 55,44 | 46,62 | 51,13 | 24,3 | 6,3 | |
| 46,93 | 51,55 | 56,32 | 47,36 | 52,02 | 24,5 | 6,4 | |
| 47,66 | 52,44 | 57,20 | 48,10 | 52,92 | 24,7 | 6,5 | |
| 48,40 | 53,32 | 58,08 | 48,84 | 53,82 | 24,9 | 6,6 | |
| 49,13 | 54,21 | 58,96 | 49,58 | 54,72 | 25,1 | 6,7 | |
| 49,86 | 55,11 | 59,84 | 50,32 | 55,62 | 25,3 | 6,8 | |
| 50,60 | 56,01 | 60,72 | 51,06 | 56,52 | 25,5 | 6,9 | |
| 51,33 | 56,91 | 61,60 | 51,80 | 57,43 | 25,7 | 7,0 | |

Table II

| cc. $\frac{n}{2}$ KOH | E. V. (A. V.; S. V.) | C ₁₀ H ₁₈ O | | | | C ₁₀ H ₂₀ O | |
|--------------------------|----------------------------|-----------------------------------|---------|---------|--------------------------------|-----------------------------------|---------|
| | | Triglate | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol |
| 7,1 | | 55,85 | 46,38 | 36,44 | 40,47 | 46,86 | 36,92 |
| 7,2 | | 56,64 | 47,04 | 36,96 | 41,10 | 47,52 | 37,44 |
| 7,3 | | 57,43 | 47,69 | 37,47 | 41,73 | 48,18 | 37,96 |
| 7,4 | | 58,21 | 48,34 | 37,98 | 42,37 | 48,84 | 38,48 |
| 7,5 | | 59,00 | 49,00 | 38,50 | 43,02 | 49,50 | 39,00 |
| 7,6 | | 59,79 | 49,65 | 39,01 | 43,66 | 50,16 | 39,52 |
| 7,7 | | 60,57 | 50,30 | 39,52 | 44,30 | 50,82 | 40,04 |
| 7,8 | | 61,36 | 50,96 | 40,04 | 44,95 | 51,48 | 40,56 |
| 7,9 | | 62,15 | 51,61 | 40,55 | 45,60 | 52,14 | 41,08 |
| 8,0 | | 62,93 | 52,26 | 41,06 | 46,25 | 52,80 | 41,60 |
| 8,1 | | 63,72 | 52,92 | 41,58 | 46,90 | 53,46 | 42,12 |
| 8,2 | | 64,51 | 53,57 | 42,09 | 47,55 | 54,12 | 42,64 |
| 8,3 | | 65,29 | 54,22 | 42,60 | 48,20 | 54,78 | 43,16 |
| 8,4 | | 66,08 | 54,88 | 43,12 | 48,86 | 55,44 | 43,68 |
| 8,5 | | 66,87 | 55,53 | 43,63 | 49,53 | 56,10 | 44,20 |
| 8,6 | | 67,65 | 56,18 | 44,14 | 50,19 | 56,76 | 44,72 |
| 8,7 | | 68,44 | 56,84 | 44,66 | 50,85 | 57,42 | 45,24 |
| 8,8 | | 69,23 | 57,49 | 45,17 | 51,51 | 58,08 | 45,76 |
| 8,9 | | 70,01 | 58,14 | 45,68 | 52,18 | 58,74 | 46,28 |
| 9,0 | | 70,80 | 58,80 | 46,20 | 52,86 | 59,40 | 46,80 |
| 9,1 | | 71,59 | 59,45 | 46,71 | 53,54 | 60,06 | 47,32 |
| 9,2 | | 72,37 | 60,10 | 47,22 | 54,21 | 60,72 | 47,84 |
| 9,3 | | 73,16 | 60,76 | 47,74 | 54,89 | 61,38 | 48,36 |
| 9,4 | | 73,95 | 61,41 | 48,25 | 55,57 | 62,04 | 48,88 |
| 9,5 | | 74,73 | 62,06 | 48,76 | 56,25 | 62,70 | 49,40 |
| 9,6 | | 75,52 | 62,72 | 49,28 | 56,93 | 63,36 | 49,92 |
| 9,7 | | 76,31 | 63,37 | 49,79 | 57,61 | 64,02 | 50,44 |
| 9,8 | | 77,09 | 64,02 | 50,30 | 58,30 | 64,68 | 50,96 |
| 9,9 | | 77,88 | 64,68 | 50,82 | 59,00 | 65,34 | 51,48 |
| 10,0 | | 78,67 | 65,33 | 51,33 | 59,69 | 66,00 | 52,00 |
| 10,1 | | 79,45 | 65,98 | 51,84 | 60,38 | 66,66 | 52,52 |
| 10,2 | | 80,24 | 66,64 | 52,36 | 61,08 | 67,32 | 53,04 |
| 10,3 | | 81,03 | 67,29 | 52,87 | 61,78 | 67,98 | 53,56 |
| 10,4 | | 81,81 | 67,94 | 53,38 | 62,48 | 68,64 | 54,08 |
| 10,5 | | 82,60 | 68,60 | 53,90 | 63,19 | 69,30 | 54,60 |
| 10,6 | | 83,39 | 69,25 | 54,41 | 63,90 | 69,96 | 55,12 |
| 10,7 | | 84,17 | 69,90 | 54,92 | 64,61 | 70,62 | 55,64 |
| 10,8 | | 84,96 | 70,56 | 55,44 | 65,32 | 71,28 | 56,16 |
| 10,9 | | 85,75 | 71,21 | 55,95 | 66,03 | 71,94 | 56,68 |
| 11,0 | | 86,53 | 71,86 | 56,46 | 66,75 | 72,60 | 57,20 |

Table II

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| C ₁₅ H ₃₄ O | | C ₁₅ H ₃₂ O | | | E. V. (A. V.; S. V.) | cc. n 2 KOH |
|-----------------------------------|--------------------------------|-----------------------------------|---------|--------------------------------|----------------------------|----------------------|
| Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. oil | | |
| 52,06 | 57,81 | 62,48 | 52,54 | 58,34 | | 7,1 |
| 52,80 | 58,71 | 63,36 | 53,28 | 59,25 | | 7,2 |
| 53,53 | 59,62 | 64,24 | 54,02 | 60,17 | | 7,3 |
| 54,26 | 60,53 | 65,12 | 54,76 | 61,09 | | 7,4 |
| 55,00 | 61,45 | 66,00 | 55,50 | 62,01 | | 7,5 |
| 55,73 | 62,36 | 66,88 | 56,24 | 62,93 | | 7,6 |
| 56,46 | 63,28 | 67,76 | 56,98 | 63,86 | | 7,7 |
| 57,20 | 64,21 | 68,64 | 57,72 | 64,80 | | 7,8 |
| 57,93 | 65,14 | 69,52 | 58,46 | 65,74 | | 7,9 |
| 58,66 | 66,07 | 70,40 | 59,20 | 66,67 | | 8,0 |
| 59,40 | 67,00 | 71,28 | 59,94 | 67,61 | | 8,1 |
| 60,13 | 67,93 | 72,16 | 60,68 | 68,55 | | 8,2 |
| 60,86 | 68,87 | 73,04 | 61,42 | 69,50 | | 8,3 |
| 61,60 | 69,81 | 73,92 | 62,16 | 70,45 | | 8,4 |
| 62,33 | 70,75 | 74,80 | 62,90 | 71,40 | | 8,5 |
| 63,06 | 71,69 | 75,68 | 63,64 | 72,35 | | 8,6 |
| 63,80 | 72,64 | 76,56 | 64,38 | 73,31 | | 8,7 |
| 64,53 | 73,60 | 77,44 | 65,12 | 74,27 | | 8,8 |
| 65,26 | 74,56 | 78,32 | 65,86 | 75,23 | | 8,9 |
| 66,00 | 75,52 | 79,20 | 66,60 | 76,20 | | 9,0 |
| 66,73 | 76,48 | 80,08 | 67,34 | 77,17 | | 9,1 |
| 67,46 | 77,44 | 80,96 | 68,08 | 78,14 | | 9,2 |
| 68,20 | 78,41 | 81,84 | 68,82 | 79,12 | | 9,3 |
| 68,93 | 79,38 | 82,72 | 69,56 | 80,10 | | 9,4 |
| 69,66 | 80,35 | 83,60 | 70,30 | 81,08 | | 9,5 |
| 70,40 | 81,33 | 84,48 | 71,04 | 82,06 | | 9,6 |
| 71,13 | 82,31 | 85,36 | 71,78 | 83,05 | | 9,7 |
| 71,86 | 83,30 | 86,24 | 72,52 | 84,05 | | 9,8 |
| 72,60 | 84,28 | 87,12 | 73,26 | 85,04 | | 9,9 |
| 73,33 | 85,27 | 88,00 | 74,00 | 86,04 | | 10,0 |
| 74,06 | 86,26 | 88,88 | 74,74 | 87,04 | | 10,1 |
| 74,80 | 87,26 | 89,76 | 75,48 | 88,05 | | 10,2 |
| 75,53 | 88,26 | 90,64 | 76,22 | 89,06 | | 10,3 |
| 76,26 | 89,26 | 91,52 | 76,96 | 90,07 | | 10,4 |
| 77,00 | 90,27 | 92,40 | 77,70 | 91,09 | | 10,5 |
| 77,73 | 91,28 | 93,28 | 78,44 | 92,11 | | 10,6 |
| 78,46 | 92,29 | 94,16 | 79,18 | 93,13 | | 10,7 |
| 79,20 | 93,31 | 95,04 | 79,92 | 94,16 | | 10,8 |
| 79,93 | 94,33 | 95,92 | 80,66 | 95,19 | | 10,9 |
| 80,66 | 95,35 | 96,80 | 81,40 | 96,22 | | 11,0 |

Table II

| cc. n 2 KOH | E. V. (A. V.; S. V.) | C ₁₀ H ₁₈ O | | | | C ₁₀ H ₁₆ O | | |
|----------------------|----------------------------|-----------------------------------|---------|---------|-------------------------------|-----------------------------------|---------|-------------------------------|
| | | Tiglate | Acetate | Alcohol | Alcohol in the org. oil | Acetate | Alcohol | Alcohol in the org. oil |
| 11,1 | | 87,32 | 72,52 | 56,98 | 67,46 | 73,26 | 57,72 | 68,34 |
| 11,2 | | 88,11 | 73,17 | 57,49 | 68,18 | 73,92 | 58,24 | 69,07 |
| 11,3 | | 88,89 | 73,82 | 58,00 | 68,90 | 74,58 | 58,76 | 69,80 |
| 11,4 | | 89,68 | 74,48 | 58,52 | 69,63 | 75,24 | 59,28 | 70,54 |
| 11,5 | | 90,47 | 75,13 | 59,03 | 70,36 | 75,90 | 59,80 | 71,28 |
| 11,6 | | 91,25 | 75,78 | 59,54 | 71,09 | 76,56 | 60,32 | 72,02 |
| 11,7 | | 92,04 | 76,44 | 60,06 | 71,82 | 77,22 | 60,84 | 72,76 |
| 11,8 | | 92,83 | 77,09 | 60,57 | 72,56 | 77,88 | 61,36 | 73,51 |
| 11,9 | | 93,61 | 77,74 | 61,08 | 73,30 | 78,54 | 61,88 | 74,25 |
| 12,0 | | 94,40 | 78,40 | 61,60 | 74,04 | 79,20 | 62,40 | 75,00 |
| 12,1 | | 95,19 | 79,05 | 62,11 | 74,79 | 79,86 | 62,92 | 75,75 |
| 12,2 | | 95,97 | 79,70 | 62,62 | 75,53 | 80,52 | 63,44 | 76,51 |
| 12,3 | | 96,76 | 80,36 | 63,14 | 76,27 | 81,18 | 63,96 | 77,26 |
| 12,4 | | 97,55 | 81,01 | 63,65 | 77,02 | 81,84 | 64,48 | 78,02 |
| 12,5 | | 98,33 | 81,66 | 64,16 | 77,77 | 82,50 | 65,00 | 78,79 |
| 12,6 | | 99,12 | 82,32 | 64,68 | 78,53 | 83,16 | 65,52 | 79,55 |
| 12,7 | | 99,91 | 82,97 | 65,19 | 79,29 | 83,82 | 66,04 | 80,32 |
| 12,8 | | | 83,62 | 65,70 | 80,05 | 84,48 | 66,56 | 81,09 |
| 12,9 | | | 84,28 | 66,22 | 80,81 | 85,14 | 67,08 | 81,86 |
| 13,0 | | | 84,93 | 66,73 | 81,57 | 85,80 | 67,60 | 82,64 |
| 13,1 | | | 85,58 | 67,24 | 82,34 | 86,46 | 68,12 | 83,42 |
| 13,2 | | | 86,24 | 67,76 | 83,12 | 87,12 | 68,64 | 84,20 |
| 13,3 | | | 86,89 | 68,27 | 83,89 | 87,78 | 69,16 | 84,98 |
| 13,4 | | | 87,54 | 68,78 | 84,67 | 88,44 | 69,68 | 85,77 |
| 13,5 | | | 88,20 | 69,30 | 85,45 | 89,10 | 70,20 | 86,56 |
| 13,6 | | | 88,85 | 69,81 | 86,23 | 89,76 | 70,72 | 87,35 |
| 13,7 | | | 89,50 | 70,32 | 87,01 | 90,42 | 71,24 | 88,14 |
| 13,8 | | | 90,16 | 70,84 | 87,80 | 91,08 | 71,76 | 88,94 |
| 13,9 | | | 90,81 | 71,35 | 88,60 | 91,74 | 72,28 | 89,74 |
| 14,0 | | | 91,46 | 71,86 | 89,39 | 92,40 | 72,80 | 90,54 |
| 14,1 | | | 92,12 | 72,38 | 90,18 | 93,06 | 73,32 | 91,35 |
| 14,2 | | | 92,77 | 72,89 | 90,98 | 93,72 | 73,84 | 92,16 |
| 14,3 | | | 93,42 | 73,40 | 91,78 | 94,38 | 74,36 | 92,97 |
| 14,4 | | | 94,08 | 73,92 | 92,58 | 95,04 | 74,88 | 93,78 |
| 14,5 | | | 94,73 | 74,43 | 93,39 | 95,70 | 75,40 | 94,60 |
| 14,6 | | | 95,38 | 74,94 | 94,20 | 96,36 | 75,92 | 95,42 |
| 14,7 | | | 96,04 | 75,46 | 95,01 | 97,02 | 76,44 | 96,25 |
| 14,8 | | | 96,69 | 75,97 | 95,83 | 97,68 | 76,96 | 97,08 |
| 14,9 | | | 97,34 | 76,48 | 96,65 | 98,34 | 77,48 | 97,90 |
| 15,0 | | | 98,00 | 77,00 | 97,47 | 99,00 | 78,00 | 98,73 |

Table II

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| Acetate | C ₁₀ H ₁₆ O | | Acetate | C ₁₀ H ₁₆ O | | E. V. (A. V.; S. V.) | cc. n 2 KOH |
|---------|-----------------------------------|--------------------------------|---------|-----------------------------------|--------------------------------|----------------------------|-------------------|
| | Alcohol | Alcohol in the orig. oil | | Alcohol | Alcohol in the orig. oil | | |
| 96.94 | 81,40 | 96,38 | 97,68 | 82,14 | 97,25 | 11,1 | |
| 97,81 | 82,13 | 97,41 | 98,56 | 82,88 | 98,29 | 11,2 | |
| 98,68 | 82,86 | 98,44 | 99,44 | 83,62 | 99,33 | 11,3 | |
| 99,56 | 83,60 | 99,48 | 100,32 | 84,36 | 100,38 | 11,4 | |
| 100,43 | 84,33 | 100,51 | — | — | — | 11,5 | |
| — | — | — | — | — | — | 11,6 | |
| — | — | — | — | — | — | 11,7 | |
| — | — | — | — | — | — | 11,8 | |
| — | — | — | — | — | — | 11,9 | |
| — | — | — | — | — | — | 12,0 | |
| — | — | — | — | — | — | 12,1 | |
| — | — | — | — | — | — | 12,2 | |
| — | — | — | — | — | — | 12,3 | |
| — | — | — | — | — | — | 12,4 | |
| — | — | — | — | — | — | 12,5 | |
| — | — | — | — | — | — | 12,6 | |
| — | — | — | — | — | — | 12,7 | |
| — | — | — | — | — | — | 12,8 | |
| — | — | — | — | — | — | 12,9 | |
| — | — | — | — | — | — | 13,0 | |
| — | — | — | — | — | — | 13,1 | |
| — | — | — | — | — | — | 13,2 | |
| — | — | — | — | — | — | 13,3 | |
| — | — | — | — | — | — | 13,4 | |
| — | — | — | — | — | — | 13,5 | |
| — | — | — | — | — | — | 13,6 | |
| — | — | — | — | — | — | 13,7 | |
| — | — | — | — | — | — | 13,8 | |
| — | — | — | — | — | — | 13,9 | |
| — | — | — | — | — | — | 14,0 | |
| — | — | — | — | — | — | 14,1 | |
| — | — | — | — | — | — | 14,2 | |
| — | — | — | — | — | — | 14,3 | |
| — | — | — | — | — | — | 14,4 | |
| — | — | — | — | — | — | 14,5 | |
| — | — | — | — | — | — | 14,6 | |
| — | — | — | — | — | — | 14,7 | |
| — | — | — | — | — | — | 14,8 | |
| — | — | — | — | — | — | 14,9 | |
| — | — | — | — | — | — | 15,0 | |

Table II

| cc. n 2 KOH | E. V. (A. V.; S. V.) | C ₁₀ H ₁₈ O | | | | C ₁₂ H ₂₂ O | | |
|-------------------|----------------------------|-----------------------------------|---------|---------|--------------------------------|-----------------------------------|---------|----------------------------|
| | | Tiglate | Acetate | Alcohol | Alcohol in the orig. oil | Acetate | Alcohol | Alcohol in the orig. |
| 15,1 | | — | 98,65 | 77,51 | 98,29 | 99,66 | 78,52 | 99,2 |
| 15,2 | | — | 99,30 | 78,02 | 99,12 | 100,32 | 79,04 | 100,4 |
| 15,3 | | — | 99,96 | 78,54 | 99,95 | — | — | — |

Table II

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| Acetals | $C_{15}H_{34}O$ | | Acetate | $C_{15}H_{32}O$ | | E. V. (A. V.; S. V.) | cc. n 2 KOH |
|---------|-----------------|--------------------------------|---------|-----------------|--------------------------------|----------------------------|-------------------|
| | Alcohol | Alcohol in the orig. oil | | Alcohol | Alcohol in the orig. oil | | |
| — | — | — | — | — | — | 15.1 | 15.1 |
| — | — | — | — | — | — | 15.2 | 15.2 |
| — | — | — | — | — | — | 15.3 | 15.3 |

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